Wayne State University Radiation Safety Manual

Office of Environmental Health and Safety
Radiation Safety-Health Physics
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Detroit, Michigan 48202
www.oehs.wayne.edu

Version 2.10

EMERGENCY CONTACT INFORMATION

Office of Environmental Health and Safety………………………………… 313-577-1200
Wayne State University Police Department………………………………313-577-2222

Radiation Emergency Response

If this emergency involves a fire, explosion, or any other situation where your life or health is in immediate danger, evacuate the area and contact the WSU Police Department at 577-2222 from a safe location. While on the phone with the police dispatcher, be sure to let them know:

- The location of the emergency
- The nature of the emergency
- The types of hazardous materials involved (radiation, biohazards, or chemicals,)
- Your name
- Your current location

Stay at the phone until help arrives. Emergency response personnel will want to make sure you are not injured and may need your help to properly address the situation. **DO NOT LEAVE THE AREA UNTIL HELP ARRIVES!**

If the situation permits, secure your radioactive and other hazardous material as best you can prior to evacuating the lab. Return radioactive material to the storage area, place hazardous liquids in spill trays or pans, and pour bleach on infectious material. Shut off any gas appliances, centrifuges, fume hoods, and other lab equipment. Close windows and doors as you are vacating the area.

If the emergency involves a personal contamination, **DO NOT LEAVE THE LAB** unless a situation exists which places your life in immediate danger. Call the OEHS Health Physics staff at 313-577-1200, and make sure the person answering the phone understands the situation involves a personal contamination with radioactive material. If there is no response the WSU Police Department may be called at 577-2222.

When evaluating a contamination, perform a complete survey of your person to determine the areas of contamination. If the radioisotope can be detected with a survey instrument, take note of the count rate of the area of contamination to assist the health physicist upon arrival. Contaminated clothing should be removed as quickly as possible and placed in a bag or other container to prevent the spread of contamination. You may begin to decontaminate skin and hair by **GENTLY** washing with liquid soap and warm water. **DO NOT SCRUB, USE ABRASIVES OR OTHER CHEMICALS TO DECONTAMINATE SKIN.** If gentle washing with soap and water fails to remove the contamination, the Health Physicist will assist with further decontamination. Perform an area survey to determine the extent of contamination and take care not to spread contamination or become contaminated. If possible, begin to mark the perimeters of the contaminated areas. Above all else, **STAY IN THE AREA** and wait for the Health Physics staff to arrive.

If a member of the lab is experiencing a medical emergency and radioactive material is involved, **PROVIDE FIRST AID WITHOUT REGARD TO THE RADIOACTIVE CONTAMINATION!** Research labs at Wayne State University do not use quantities of radioactive material that create an immediate danger to the life or health of a first responder. If the situation permits, the injured person may be decontaminated, or moved out of the contaminated area. Call the WSU Police at 577-2222, and make sure the dispatcher is aware that the situation involves both a medical emergency and radioactive material.

TABLE OF CONTENTS

APPENDICES

i. General

These rules and regulations do not provide complete information on radiological health protection but are intended to outline procedures approved by the Wayne State University Radiation Safety Committee. Individual users of ionizing radiation should familiarize themselves with the applicable US Nuclear Regulatory Commission and State of Michigan regulations covering radiation protection.

The Radiation Safety Committee may amend or modify these rules and regulations from time to time. Such amendments shall become effective when published.

The Committee may impose requirements, as it deems appropriate or necessary, to protect health or to minimize danger to property. These requirements may go beyond the scope of applicable Federal and State regulations.

Any source of ionizing radiation to be brought onto or to leave Wayne State University property must be processed through the Office of Environmental Health and Safety. Only authorized users of ionizing radiation may procure, possess, use or store radioactive material or radiation-generating machines. Authorization to use ionizing radiation at Wayne State University may only be granted by the Radiation Safety Committee. Interim authorization may be granted by the Radiation Safety Officer for certain low-hazard radionuclides used in common procedures. Interim authorization will only be granted in certain cases where the applicant must begin work prior to the next meeting of the Radiation Safety Committee, at which time the Committee will decide to either grant or deny full authorization.

Violations of safety practices may result in the temporary loss of Committee approval to procure or use sources of ionizing radiation until corrective measures are fulfilled. Such violations that are not corrected after reasonable notice and negotiation will be reported to the appropriate Vice President, Dean or Department Chair and the responsible Principal Investigator will be stripped of the privilege to use ionizing radiation.

The Committee may, upon application by interested persons or upon its own initiative, grant exemptions from the requirements of these regulations which will not result in undue hazard, and which are in agreement with all applicable Federal and State regulations. Such exemptions will be considered solely on a case-by-case basis and may be revoked by the Committee at any time.

Plans and specifications for the construction of new radiation facilities, or the major modification of existing facilities, shall be approved by the Committee prior to the start of construction or renovation. The approval of such plans shall not preclude the requirement of additional modifications should a subsequent analysis of operating conditions indicate the possibility of a violation of the University's ALARA policy.

ii. Rules for Radiation Safety

1. Do not eat, drink or smoke in radiation use, storage or disposal areas. "Eating" includes gum, candy, beverages and chewing tobacco. Do not apply cosmetics, take medications or insert/remove contact lenses in the laboratory. Do not dispose of food, empty food wrappers or containers anywhere in the lab.

2. Food and beverages may not be stored anywhere in a radioisotope lab.

3. Gloves should be worn during any and all operations in which contamination of the hands is possible.

4. Never pipette liquids by mouth.

5. Store and transport radioactive materials in containers which will prevent breakage and spillage. Secondary containment is important; when transporting radioactive materials, use trays and carts.

6. Use ventilation hoods or glove boxes if the radioactivity may become airborne and for high activity uses, such as manipulation of stock solutions.

7. The individual(s) responsible for any contamination will be required to decontaminate the area of concern.

8. Check your hands, clothing, and shoes for contamination prior to leaving the lab after working with radioactive material.
9. Always dispose of radioactive waste in a radioactive waste container.

10. Always wear your assigned dosimetry badge(s) when working with ionizing radiation.

11. Wear lab coats when working with radioactive materials. Lab coats should be buttoned up, not worn open.

12. Users of high energy beta or gamma radionuclides should wear eye protection, such as safety glasses or eyeglasses.

iii. Radiation Incidents/Emergencies

When reporting a radiation incident, please be prepared to provide the following information to the Health Physics staff or other emergency responder:

- Radionuclide involved
- Amount of radioactivity
- Chemical form of released material, other hazardous chemicals involved
- Volume or released material
- Location of incident (building and room number)
- Persons contaminated or exposed, estimate of amount (e.g., 2,000 CPM, ^{32}P, 10 cm^2 on skin of arm)
- Any injuries, what they are, how serious
- Air borne radioactivity present or not
- What you have done so far
- Principal investigator name

- Name of person reporting
- Telephone number where you can be reached

Some radiological incidents involve serious risk to life, health or property. In the event of serious injury coupled with exposure to radiation, fire, explosion, major release of health threatening materials or serious radiation exposure, an ambulance may be dispatched, and victims will be transported to a hospital for treatment. Upon arrival at the hospital, the victims(s) will be met by appropriate radiation safety personnel who will monitor the treatment and decontamination procedure.

iii.a First Response and Reporting to Health Physics

Incidents may occur during the use of radioactive materials, such as spills, accidental releases into the air, contamination of the worker or the work area, and numerous other possible problems. When an incident occurs, the worker must first make a judgment as to whether the incident is a minor incident, major incident or emergency. Subsequent actions are based on this decision.

A *minor incident* with radioactive materials is an abnormal occurrence involving low amounts of radioactive materials, where the worker handling the spill knows how to clean it up, has the decontamination materials on hand, and can respond without incurring risk of exposures or spreading within a reasonably short time.

A *major incident* is an abnormal occurrence involving high amounts of radioactive materials, high risk nuclides, large area of contamination, contamination of the skin, airborne radioactivity, or any situation where contamination may have been spread outside the authorized area. Major spills must be reported to the Radiation Safety Officer or his/her designee immediately, as required by federal law. Call the OEHS during working hours; dial 577-2222 during non-working hours.

An *emergency* is an incident which involves serious injury or death, fire, explosion, or significant release of a health or life-threatening material, which is or may be coupled with a minor or major radiological incident. DIAL 577-2222 IMMEDIATELY IF AN EMERGENCY HAS OCCURRED!!

In the event of a **MINOR** incident, these procedures should be followed:

1. Notify the principal investigator and persons in the area that an incident has occurred.
2. Contain the spill. Cover with absorbent paper or dike with absorbent.
3. Isolate the area to prevent unnecessary spread and personnel exposures.
4. Survey using the appropriate monitoring equipment in order to evaluate the presence of contamination on an individual's skin and clothing and on lab equipment. If skin or clothing contamination is present, a major spill has occurred. Contact the OEHS immediately.
5. Using disposable gloves, carefully fold up the absorbent paper and pad and deposit in an appropriate radioactive waste container.
6. Survey the area of the spill to determine the extent.
7. Decontaminate the spill using decontaminant detergent (available from Science Stores), and resurvey. When cleaning a contaminated area, work from the perimeter of the contamination inwards, while taking care not to spread contamination back into areas that are clean. Rinse cleaning materials and change rinse water frequently.
8. Continue step 7 until the area is decontaminated completely.
    1. Document spill in radiation survey log book.

In the event of a **MAJOR** incident, the following procedure should be instituted:

1. Notify all persons in the area that a major spill or incident has occurred and evacuate unnecessary personnel. Notify the principal investigator.
2. If possible, prevent the spreading of the radioactive material by using absorbent paper. Do not attempt to clean it up. Confine all potentially contaminated individuals in order to prevent the further spread of contamination.
3. If possible, shield the source, but only if it can be done without significantly increasing your radiation exposure.
4. Leave the affected room and lock the doors to prevent entry. Attempt to prevent further contamination or spreading to unrestricted areas. (Hallways, non-radiation laboratories, etc., are unrestricted areas.)
5. Contact the Radiation Safety Officer if the spill occurs during normal work hours. Call the Department of Public Safety, 577-2222, after normal working hours.
6. Remove all contaminated clothing and wait for instructions concerning cleanup from the Radiation Safety Officer.
7. If skin contamination has occurred, measure levels of contamination with a survey meter, record, and begin decontamination by gentle washing with warm water and soap, washing downwards towards extremities, not upwards.

In the event of an **EMERGENCY** in which ionizing radiation is involved, the following procedure should be instituted:

1. Notify all persons in the area that an EMERGENCY has occurred and evacuate the area if a risk to persons present exists.

2. Dial (57)7-2222 and NOTIFY of the nature emergency, using the reporting guidelines previously listed in this section.

2. AWAIT THE EMERGENCY RESPONDERS who will assist and provide direction, as well as contact any other necessary responders.

All incidents involving ionizing radiation must be reported as soon as possible to the principal investigator. If the principal investigator is not available, notify the OEHS, who will advise and assist with the problem.

iii.b Decontamination and Monitoring

When radioactive material is in an unwanted or unplanned location, it is called contamination. This may be floors, equipment, work areas, storage areas, people or areas outside the authorized radiation use laboratory. Fortunately, most radioactive contamination and/or spills are easy to clean to background levels in a reasonable time and with reasonable cost. Some methods of decontamination are as follows:

Liquid Radioactive Decontaminant: Concentrated liquid decontaminating agents are available from Science Stores and most scientific suppliers. This detergent is diluted with water and rapidly and easily cleans radioactive contamination without excessive effort. Mild wiping or scrubbing will remove most contamination using this detergent. When using liquid detergents, add as little liquid to the contaminated area as possible to prevent the spread of contamination. Always work from the perimeter of a contamination inwards, taking care not to spread contamination back into clean areas. Cleaning materials must be rinsed frequently, and rinse water disposed of as radioactive waste. Note that these detergents contain a carcinogen, so the Material Safety Data Sheet should be read by new radiation users so that they are aware of the hazards. In dilute liquid form, radioactive decontaminants do not present a significant hazard to handlers unless ingested or splashed in eyes. Avoid prolonged skin contact with the concentrated material.

Most radioisotopes used in biomedical research may be effectively cleaned with common household cleaning solutions, and expensive decontamination solutions with chelating agents are not required. The Health Physics staff will be happy to consult with you on all aspects of radioactive spill prevention, response and decontamination.

Foam Spray Decontaminant: A variety of foam spray decontamination products are available which are marketed as radioactive decontaminants. However, many other foam cleaning products accomplish decontamination just as effectively at a much lower cost; most of these are marketed in any store as bathroom or kitchen cleaning agents. Spray the foam on the contaminated areas, let sit for a few minutes, and then wipe off with a dry paper towel.

Other Decontaminating Agents: Many other agents will work to clean radioactive contamination that has been resistant to the above methods. Contact a Health Physics Specialist for assistance with difficult to remove contamination. We will help identify a method of decontamination which will work for your particular surface, radionuclide, chemical form and location. Depending on these factors, effective solutions to the problem will be identified.

Contamination on Skin: Use lukewarm (not hot or cold) water and a mild cleaning agent, such as soap. Do not rub hard or scrub with abrasives, which may break the surface of the skin. Clean the affected area in a downwards fashion, with the grain of the skin and hair, not against it, and towards the tips of extremities, not upwards. Check the area after gentle drying. If still contaminated, use a cream hand cleaner which contains no abrasives. Remember to notify the Radiation Safety Officer immediately if personnel contamination occurs or is suspected. Also, note the readings of radioactive contamination detected with the survey instrument and the times that it was discovered and then removed.

Introduction

In every facility where hazardous materials are utilized, it is necessary to maintain a policy document which establishes specific methods and procedures to develop and maintain safety and compliance. Safety is the practice of a set of rules, guidelines and procedures, which protect workers, facilities, the general public and the environment. Compliance is the maintenance of procedures, practices, documents and records which demonstrate that federal, state and local laws and regulations are not compromised. It is a necessary challenge for all administrators, safety committee members, faculty, staff, students and workers to maintain safety and compliance. In laboratory and research facilities, the challenge is accentuated with the myriad of procedures and materials utilized, and the continuous change and evolution of these conditions.

This document will serve as a guide to meeting this challenge by defining the structure, policy, procedures, responsibility, and regulatory stance set forth by the U.S. Nuclear Regulatory Commission (NRC), the State of Michigan, the Wayne State University NRC license, the Radiation Safety Committee (RSC), the Office of Environmental Health and Safety (OEHS). However, it is important that all principal investigators and workers remember that the burden of daily compliance and safe practices is their own, and that they are the most critical link in the maintenance of these goals.

1.0 The Radiation Safety Committee and Radiation Safety Officer

The Wayne State University's Radiation Safety Committee is comprised of faculty, administrators and staff who have been delegated responsibility for radiological health, safety and compliance at the University. Approval for use of radioactive materials, reviewing policy and campus radiation safety, advising the university administration in radiation safety issues and programs, and auditing the operations and activities of the OEHS Health Physics staff are some of the functions performed by the RSC.

Radiation Safety Committee members are appointed by the University administration, according to their experience and skills, which enable them to effectively perform their duties. Radiation Safety Committee members' qualifications are reviewed by the NRC, then members are named in our broad license as being responsible for oversight and review of campus radiation safety. The Radiation Safety Committee members have expertise in the wide range of uses of radioactive materials at Wayne State University. Current members of this committee are listed in the OEH&S office.

The Radiation Safety Committee shall have the following responsibilities:

Review all applications for the use of all radiation sources within the University from the standpoint of radiological health and safety, and other factors the Committee may wish to establish for the use of ionizing radiation.

Review and approve all proposed purchases and installations of radiation-generating machines, to include facility design.

Prescribe special conditions which may be necessary, such as physical examinations, additional training, designation of limited area or location of use, waste disposal methods, machine interlocks, warning signs or alarms, etc.

Review records and receive reports from the Radiation Safety Officer or other individuals responsible for health and safety practices.

Recommend remedial action when a person fails to observe safety rules and recommendations.

Keep a record of actions taken by the Committee.

The Radiation Safety Officer is the individual named on the USNRC Radioactive Materials License as being directly responsible for the management of all licensed activities at the University. These responsibilities include, but are not limited to:

1. Administration of the Health Physics section of the Office of Environmental Health and Safety.
2. Receipt and distribution of all radioactive material entering the University.
3. Licensing, inspection, and inventory of radiation-generating machines.
4. Recommending operational procedures regarding the safe handling and use of ionizing radiation.
5. Maintenance of an inventory record system to record all radioactive materials entering and leaving the University.
6. Administration of personnel monitoring program, including the maintenance of all necessary records.
7. Systematic inspection of all areas where ionizing radiation is used or stored to determine the extent to which safety requirements are being met.
8. Disposal of radioactive wastes.
9. The submission of reports to the Radiation Safety Committee on the activities of the Health Physics section, and on findings revealed by inspections. The Radiation Safety Officer shall be directly responsible to the Chair of the Radiation Safety Committee.
10. Assist the Committee in the development of such safety programs as may seem desirable.
11. Take immediate charge in the case of all accidents where ionizing radiation has been involved and to take such measures as may be required to return the area to a safe operating condition.
12. Report on behalf of the Committee as may be required by the Federal, State, and municipal agencies concerned with radiological health and safety.

2.0 Responsibilities of the Principal Investigator

Principal investigators are directly responsible for compliance with all regulations governing radiation safety in the laboratory, and for safe practices of individuals working under their supervision. Principal investigators are obligated to:

1. Ensure that individuals working under their control are properly supervised and trained to enable safe working habits and prevent exposures to themselves and others and/or contamination of the work areas or environment. Inadequate supervision and lack of training have been cited as indicative of negligence in lawsuits involving radiation.

2. Be aware of the potential radiation hazards inherent in a proposed activity; be responsible for instructing personnel in safe practices and directing personnel to sources of information concerning safe practices.

3. Maintain an accurate inventory of the various forms (physical and chemical) and quantities of radioactive material present in their work areas.

4. Avoid any unnecessary exposure, either to themselves or to other workers.

5. Understand the risks associated with the possession, use and shipment of all radioactive materials. Federal and state regulations control the use and shipping of radioactive materials and certain other hazardous substances.

6. Keep current records of the receipt and the disposition of radioactive material in their possession including use in research, waste disposal, transfer, and storage.

7. Maintain constant surveillance and immediate control of radioactive materials to prevent unauthorized removal or tampering, and/or assure that all of the workers occupying the area maintain security.

8. Post warnings and restrict entry to areas that contain radioactive material, radiation generating machines or hazardous chemicals. Label equipment and work areas dedicated to radioactive material handling.

9. Notify the OEHS of any personnel changes, including addition or termination of employees, or changes of areas where radioactive materials may be used or stored.

10. Ensure that ***all*** radiation workers understand the risks associated with working with ionizing radiation during pregnancy, and the concept of Declared Pregnancy. (NRC Reg. Guide 8.13).

11. Designate a responsible individual to oversee radioisotope work during short absences, and a stand-in principal investigator with the required committee approvals during extended absences (greater than 60 days).

12. Ensure that radiation safety surveys and audits in the laboratory are conducted and maintain proper and organized records for review.

13. Be aware of regulations and requirements pertaining to the use of ionizing radiation; maintain compliance and a safe working area.

14. Review laboratory protocols and practices in the instance of contamination or incompliance, and immediately report the corrective actions to the Radiation Safety Officer.

15. Maintain use, inventory and contamination survey logs for all radioisotopes contained in the lab, using the required forms given in Appendices M through O in this manual.

16. Use ionizing radiation according to statements, representations and conditions set forth in the ionizing radiation use approval given by the Radiation Safety Committee.
    Changes from the approved procedures must be approved by the Committee in an amendment or new application prior to the implementation of the change.

Failure to comply with the rules and regulations set forth above and throughout this manual may lead to disciplinary actions and/or the cessation of ionizing radiation shipments and experiments. The Radiation Safety Officer and/or the Radiation Safety Committee may terminate any ionizing radiation use and/or research if deemed necessary. Suspension or termination of approval to use ionizing radiation may result from situations jeopardizing health and safety, the environment or the WSU broad license / machine license.

3.0 Responsibilities of the Worker

Individuals who use ionizing radiation assume certain responsibilities in their work. The individual worker is the "first line of defense" in protection of people and the environment against undue risks of radiation exposure and/or contamination. Since the workers, themselves, are the direct handlers of the radioactive material or radiation generating machine, the final responsibility lies with them for safety and compliance with laws and regulations. For this reason, it is critical that they be aware of the risks, safe practices and requirements for use of ionizing radiation.

The term "worker" is used by the University to identify an individual who uses ionizing radiation in the course of his/her employment or studies. Workers may be principal investigators, graduate students, undergraduate students, technicians, post-doctorates, visitors, or any other individual who will work with ionizing radiation. The following items are to be adhered to at all times by radiation workers.

1. Each worker must attend the appropriate OEHS training classes, including radiation and chemical safety. Workers are prohibited from working with ionizing radiation until they have attended the basic radiation safety class and passed the examination with a minimum score of 75%. Radiation workers must attend a refresher session each year.

2. The worker must receive additional instruction from the Principal Investigator or Laboratory Manger on safe work procedures in the research laboratory. This training must be documented on the form provided in Appendix L of this manual. The training form is to be kept in the Radiation Safety Logbook and must be available for inspection.

3. Workers are responsible for adhering to all laws, rules, regulations, license conditions and guidelines pertaining to the use of ionizing radiation.

4. Workers must wear their assigned radiation dosimeter during uses of ionizing radiation. (See Personnel Monitoring for details on dosimeter requirements.)

5. Workers must practice ALARA (As Low As Reasonably Achievable) in their work, and minimize the potential for exposures, contamination or release of radioactive materials.

6. Radiation work areas must be monitored by the user after each use of radioactive material, and the contamination survey must be documented. If contamination is found, it must be cleaned up.

7. No changes in experimental procedures using ionizing radiation are to occur without the approval of the principal investigator. Do not take short cuts. Changes in experimental procedures impacting upon safety (higher quantities, higher risk, use in animals, etc.) must be approved by the WSU Radiation Safety Committee.

8. Any abnormal occurrence must be reported immediately to the principal investigator, such as spills, significant contamination, equipment failure, loss of radiation

dosimeters and unplanned release. If the principal investigator cannot be reached, contact the OEHS Health Physics staff.

9. It is the responsibility of the worker to clean any contamination or spills that occur in their work area. DO NOT LEAVE IT FOR ANOTHER PERSON TO CLEAN UP.

10. Workers are responsible for returning radiation dosimeters on time and reporting any loss, non-occupational exposure or contamination of the dosimeter to the OEHS.

11. Workers are responsible for informing the OEHS of any exposures which have occurred at a previous employer when beginning employment at WSU. They are also responsible for notifying the OEHS of termination of employment and returning the radiation dosimeter at the end of their employment.

12. Workers are responsible for maintaining security of radioactive materials. (See section on Security of Radioactive Materials).

4.0 Sanctions for Non-Compliance

The Radiation Safety Committee may impose requirements, as it deems appropriate and necessary, to protect health, minimize danger to property, and maintain compliance with all Federal, State, and municipal regulations.
Violations of safety practices may result in the loss of Committee approval to use sources of ionizing radiation until corrective measures are fulfilled. Such violations which are not corrected after reasonable notice and discussion will be reported by the Committee to the Dean of the School and/or the Vice President for Research.

5.0 The Wayne State University Broad Scope License and Radiation Generating Machine Licenses

Wayne State University operates under the U.S. Nuclear Regulatory Commission License Number 21-00741-08. This license is a Type A broad scope license. Type A broad licenses may only be given to large facilities that have a long history of radioactive materials use with a good safety record. It allows Wayne State University the privilege of using large varieties of radioactive materials. Large amounts of activity are authorized and may then be used in many locations, with many procedures and users that change frequently. The broad license confers authority upon the University to approve, manage and control the receipt, use and disposal of radioactive materials. In fact, the University acts to "police" itself under the authority given in a broad license.

The broad license has one feature which must always be remembered by each radioactive materials user: **there is only one license for the entire university, and any individual or action which jeopardizes the license endangers the permission of all researchers to utilize radioactive material at WSU**. If, for any reason, the license is suspended or terminated, no individual or principal investigator may use radioactive materials of any kind until the license is reinstated. Therefore, this license places significant responsibility on each individual who uses radioactive materials to comply with safe work practices, and to conduct and complete all required compliance duties, however large or small they may be.

Radiation-generating machines are individually licensed by the State of Michigan. It is the Principal Investigator's responsibility to ensure that all safety features of the machine (interlocks, beam guards, emergency power cut-offs, warning lights and alarms, etc.) remain functional and are used at all times. The OEHS Health Physics staff will perform licensing and renewal inspections of each radiation generating machine and may lock-out any machine or facility that fails to meet the safety standards set forth by the State of Michigan and the Radiation Safety Committee.

6.0 Approvals for Use of Ionizing Radiation

Approval for the use of radioactive materials and radiation-generating machines is given by the Radiation Safety Committee for a period of three years. Approval may be obtained by submitting a brief application describing the machine and/or requested material and quantity to be used, the location, individuals who will handle the material, the training and experience of the applicant, the training of workers, the protective equipment to be used (if any), monitoring equipment, a brief description of experimental procedures with emphasis on potential safety concerns, and waste disposal information. Applicants must have faculty status, assistant professor or greater, experienced in the use of radioactive materials and must be trained by the OEHS prior to approval. The application will be reviewed by RSC members, wherein approval may be granted.

The RSC may require additional conditions under which the use of ionizing radiation must be conducted. These conditions may extend beyond the scope of applicable Federal and State regulations if required to maintain a safe working environment at the University. The approved principal investigator may then order, receive and use the requested materials, sources or machines, but must do so according to the statements and representations made in the application, and any conditions set forth by the safety committee and all applicable local, state and federal laws, regulations and license conditions. Violations or infractions of these conditions may be cause for suspension or termination of the approval to receive and/or use ionizing radiation.

Applications for investigators must be approved directly by the Radiation Safety Committee, regardless of previous approvals. Application for use and storage of radioactive materials is completed via the web-based protocol found at http://research.wayne.edu/eprotocol/.

New applications are required for the use of a new radionuclide, for a change in experimental procedures which have an impact on safety, a change in chemical or physical form of a material previously approved, and for substantial increases in the quantity. Amendments to current approvals are given for slight increases in quantity or moderate changes in chemical form and may be obtained by submitting through the web based eprotocol link above.

7.0 Working with Ionizing Radiation at Wayne State University

7.1 Labeling Requirements

Work areas, trays, racks, stock solutions, tools, equipment, etc., which contain radioactive material or are contaminated must be identified with radioactive materials label tape. It is not reasonable to expect that each tube or vial be labeled, but the container, tray or rack that holds them must be labeled. (For example, scintillation vials do not need to be individually labeled, but the tray or box that they are stored in must have the above described label). The "rule of thumb" is that if there is radiation above the background in or on something, it must be labeled.

For contaminated equipment which is in frequent use and cannot be decontaminated, the isotope, date and maximum activity which may be present at any given time is to be written on the radioactive warning label. For equipment which is used for radioactive materials but is not contaminated (equipment which the staff wishes to identify for radioactive use), a label with the radioactive materials warning, "Caution, Radioactive Materials" may be used. Labels are not required if the equipment is not contaminated and may be removed after a contamination survey is performed on the equipment and any existing contamination cleaned.

All radioactive waste must be similarly labeled with the above described information. Bench top waste containers are to be labeled in the same method as for radioactive materials in use or storage. As soon as radioactive waste is placed in the radioactive waste container, all information on the waste tag must be filled out.

Work areas must be labeled with the “Caution: Radioactive Materials” sign or marked off with the radioactive warning label tape. If the area is seldom used for radioactive materials, the area may be labeled only for the duration of the use, providing that it is surveyed for contamination and is free of contamination before the labels are removed. If the work area is frequently used, it is best to label the area permanently.

Each room in which radioactive materials are used must bear a label on the doors into the room. These labels must have the radioactive warning symbol, and the name and telephone numbers of the principal investigator and one other person who is knowledgeable about the radioactive materials uses in the room(s). These labels are for emergency response purposes and should have the home telephone number where a responsible and knowledgeable individual may be reached in the event of emergency. These labels must not be disposed in the regular trash.

7.2 Laboratory Design and Equipment

Working with radioactive materials requires the use of specially designed laboratories and equipment and may not be conducted in offices or other unapproved locations. In fact, rooms to be used for such work must be examined and approved for the use of the types and quantities of radioactive materials to be used. This is part of the approval process. Most laboratories at Wayne State University meet the requirements for use of radiation.

Smooth, contiguous, non-absorbent surfaces such as stainless steel or linoleum are preferred in a radiation work area. A properly working chemical fume hood with flow rates of at least 100 feet per minute is required if fume hoods will be used for containing radioactive materials. Special filters and/or hood design is not generally necessary but may be prudent in special cases. The rooms used must be capable of security, or in other words must be able to be locked to maintain the security requirements for radioactive materials.

In areas where contamination is likely, surfaces should be covered with absorbent and disposable material, such as poly-backed absorbent lab paper. (The paper should have the plastic side down, absorbent side up.) If you are in the process of designing a radioisotope lab, consult the Health Physics staff for information regarding design and vendor catalogues. Work areas should be localized to minimize the possibility of contamination spread, and also because surveys must be conducted for all areas where radioactive materials are used, stored or disposed.

Equipment such as glassware, tools, syringes, etc. used in the handling of radioactive materials should not be used for other work or allowed to leave the lab unless it can be shown that the equipment is free from removable contamination. It is strongly recommended that a designated and labeled storage area be used to store this equipment. Fume hoods with flow rates of at least 100 linear feet per minute should be used whenever working with radioactive materials where the potential for vaporization/volatilization exists (as is the case during iodination), or in handling stock solutions of radiotracers, because of the high activity concentration.

7.3 Shielding Requirements and Design

In the interest of maintaining dose to radiation workers As Low As Reasonably Achievable (ALARA), the Health Physics staff will perform shielding checks during pre-authorization inspections and regular safety audits. At a minimum, 3/8" plexiglas shielding is required for sources of medium-energy beta radiation (^{32}P and ^{86}Rb), and an appropriate thickness of lead shielding will be required for sources of gamma and x-ray radiation. For low-energy photon emitters like ^{125}I, lead foil may be appropriate, while higher-energy gamma emitters like ^{51}Cr or pet tracers may require a thick lead sheet or bricks. Health Physics has surplus shielding material available for use by the research community. Please consult the radioisotope information appendices in this manual or contact the Health Physicist or Health Physics Specialist for help with shielding design.

7.4 Airborne Radioactive Materials

Radioactive materials have the potential for release into the air, causing the worker to have an uptake of the material through one or more of the routes of entry into the body, particularly inhalation. Numerous situations may cause airborne release of radioactive materials.
Contamination present in a room may create airborne radioactivity by simple movement of the air over the contamination, causing it to volatilize and spread. Most radioisotopes will be picked up by air and spread through this mechanism. This is one more good reason to keep areas free of contamination. Use of **volatile forms of radionuclide**s, such as ^{125}I for iodination, ^{3}H-sodium borohydride or tritiated water may generate airborne radioactivity. Any chemical or physical form which readily volatilizes or evaporates into the air must be considered a potential airborne radioactivity risk.

Chemical reactions may generate radioactive gases or other airborne contaminants. An example is the labeling reaction for ^{35}S methionine, which generates a methyl mercaptan reaction which liberates HCl and $^{35}SO_2$ gas. Airborne radioactivity has resulted in unnecessary intakes and area contamination in laboratories where the users were unaware of this risk and have not taken precautions to trap or contain the liberated $^{35}SO_2$.

Heating or incubating may cause evaporation or chemical reactions which release radioactive materials into the air. **Aerosols** (tiny droplets or particles) are present with all materials and pose an increased risk when handling stock solutions or other high concentrations of radionuclides. Use chemical fume hoods or biological safety cabinets for high activity, concentrated or potentially volatile radioactive materials manipulations.

Materials which have been frozen may release substantial quantities of aerosols or gaseous radioactive material when the containers are opened. There have been numerous incidents at WSU and other institutions where this has occurred and has caused significant contamination of work areas, equipment and clothing of the worker opening the containers.

Another cause of airborne radioactivity is media or solutions containing **cells, bacteria or other living organism**s. The living organisms metabolize the radioactive substrates and may produce radioactive gases or vapors as a byproduct.

When **hazardous chemical forms of the radionuclides** are used, such as radiolabeled carcinogens or toxins, increased risks are presented by the vapors, aerosols or gases present or generated in the use. In this case, the hazard present is not only radioactive, but may also pose airborne chemical risks.

In order to prevent uptake in these increased risk situations, fume hoods, biological safety cabinets or other containment must be used to protect the worker from uptake and internal deposition. Do not use clean benches (tissue culture hoods) for use of radioactive materials, or any other hazardous material. While the product is kept sterile by these hoods, the hazardous material present in the materials used are blown into the face of the worker, and into the room. Therefore, there is no protection for the worker.

In certain rare cases, respiratory protection may be necessary for certain radioisotope uses. However, respiratory protection should only be used when other means of control and containment do not provide enough protection. Respirators must be chosen carefully to ensure the proper fit and type of cartridge, and the use must be monitored carefully. For this reason, use of respirators for radioactive materials use must be pre-approved by the OEHS, documented and monitored. Prior to using respirators for any reason, fit testing and medical monitoring are required; this is in accordance with federal regulations.

If you are concerned that an intake has occurred, contact the OEHS. Bioassays or other investigational methods may be employed to determine whether an intake has actually occurred and to recommend ways to avoid such undesirable situations in the future.

7.5 Contamination Control

Good housekeeping is an important component of laboratory safety. Sloppy work habits, incorrect procedures or shortcuts, lack of containment, crowded or cluttered work areas and similar situations may cause or contribute to accidents or contamination. The following practices will assist in maintaining effective safety.

1. Maintain neat and clean work areas. Clutter, debris and crowded conditions interfere with the careful handling required in hazardous materials use.

2. Follow experimental procedures carefully. Radioisotope approvals are contingent upon following the procedures, statements and representations made in the principal investigator's approval. Departures from the procedures may place the approval in jeopardy.

3. Use absorbent poly-backed laboratory paper, with the plastic side down, to protect surfaces from inadvertent spills or splashes. Benchtops, fume hoods, trays containing samples, waste areas and floors in the radioactive work areas are some of the locations where absorbent paper is useful.

4. Use secondary containment for all radioactive solutions, samples, liquid waste or any other hazardous materials which may be spilled. Use trays, boxes, bus trays and other types of secondary containment to catch spills, splashes and possible container ruptures.

5. When transporting radioactive materials, use a cart; this will prevent accidentally dropping or tipping the container.

6. Clean up the work areas and survey for contamination after work is finished. If contamination is present, decontaminate or dispose of the contaminated materials.

7. Use tightly sealed or capped containers when moving, heating, centrifuging, or vortexing samples. Spills, evaporation, gases, container breakage or splashes may occur in any procedure where energy is put into the system.

8. Label all radioactive materials and areas where radioactive materials are used, stored or disposed.

7.6 <u>Unattended Operations</u>

An experiment is unattended if there is no one present who is knowledgeable of the operation and shutdown procedure to be followed in the event of an emergency.

- Experiments that are left unattended must have overriding controls with automatic shutdown devices to prevent system failure that could result in fire or explosion, for example, the loss of cooling water, overheating, flooding, and pressure buildup. Permanent piping, and shields or barriers if necessary, should be provided.

- Warning signs must be used if radiation, toxic fumes, or other hazardous conditions are present. Custodians, utility, or security personnel need to be warned of them.

- The laboratory entrance door should display an Emergency Notification sign naming the people to contact in case of trouble.

- All unattended electrical heating equipment must be provided with fail safe oven temperature shutoff controls, as overheating can result in a fire hazard.
- Burners, induction heaters, ovens, and furnaces must be located away from areas where temperature-sensitive and flammable materials are handled.

- Fan-cooled heating equipment must be equipped with an interlock arranged to disconnect current to the heating elements when the fan is inoperative.

- If your equipment is potentially dangerous and must be left on overnight, consult with your supervisor to see whether it is permissible to do so. Ensure that persons who may have to check the room can re-enter exterior doors (check with campus police). Notify the facilities manager (as some repair work and janitorial services are often performed during the night hours).

- Post a notice on your equipment describing possible malfunctions, emergency shutoff procedures, and the nature of the hazards.

- Bunsen and other gas burners without approved flame-failure devices must not be left on overnight. Gas pressure often fluctuates; an increase in pressure will cause a taller, hotter flame, overheating equipment and perhaps causing a fire. If the pressure decreases the flame may go out. Upon resumption of gas flow, flammable gas will accumulate to create a fire or explosion hazard.

• Over-temperature cutoff devices should be used on heated oil baths.

• Use permanent piping if you must supply water to an overnight experiment. A sudden rise in pressure due to water fluctuations may rupture plastic or rubber experimental apparatus and cause flooding of lower floors. Floor flooding also takes place when water is left running into sinks to maintain a desired level and the drain becomes blocked or plugged. Consideration should be given to the use of standing overflow devices, which make drain plugging less likely.

• Electrical extension cords shall never be left plugged in while unattended (they are for temporary use while working with portable equipment in rooms where receptacles are not available).

• Protect the cords of electrical devices that must operate unattended. Prevent chemical or physical damage to the cords, by draping cords away from foreseeable hazards and heat sources.

7.7 Contamination Survey Instruments

Every laboratory using radioactive materials must possess or have available for immediate use appropriate radiation monitoring equipment. This equipment must be in good working order and must be calibrated yearly by OEHS Health Physics staff. Results of this calibration will be forwarded to the project leader. Equipment that has not passed this annual examination must be removed from service until it is repaired or replaced. If you believe that there is a problem with your equipment, contact OEHS and arrange a time when the equipment can be inspected and calibrated.

Radioactive monitoring instruments must be capable of detecting the radioisotope being monitored at or below the contamination limits listed in the section on Radiation Surveys. To calculate the sensitivity of the survey instrument, the following formula may be used.

(Background of instrument x 2) / (Efficiency* for the isotope being measured) = Minimum Detectable Activity in DPM

Note that efficiencies are given in the OEHS calibration results.

There are several types of monitoring instruments commonly used in teaching and research laboratories. The most widely used instrument is the survey meter, a portable instrument capable of detecting medium and high-energy beta or gamma radiation, providing the appropriate detector is used. The survey meter, with either a Geiger-Muller or Low Energy Gamma Scintillation detector is the least expensive, fastest and most reliable means of detecting and measuring radioactive contamination.

The beta Geiger-Muller pancake detector is used with the survey meter for finding and measuring beta radiation and will detect all beta radioisotopes used at Wayne State University except ^{3}H, ^{14}C and ^{63}Ni. It does not detect tritium or ^{63}Ni because their betas are too low in energy to penetrate the window of the detector. ^{14}C may be detected by the Geiger-Muller beta pancake probe, but the detection efficiency is too low to be useful for lab contamination surveys. Radioisotopes which may be detected reliably with the beta pancake are ^{35}S, ^{33}P, ^{32}P, ^{45}Ca, ^{36}Cl, ^{51}Cr and other medium to high-energy beta and gamma emitting nuclides.

The low energy gamma (LEG) scintillation probe is used with the survey meter to detect and measure gamma radioisotopes of energies too low to be efficiently detected by the

Geiger-Muller pancake probe. The LEG scintillator is the detector to be used for ^{125}I and ^{73}As and will perform adequately for detecting the low energy x-rays created by shielded energetic beta emitters producing Bremsstrahlung radiation.

Another commonly used instrument is the liquid scintillation counter. It is necessary to use it in radiation safety surveys for ^{3}H, ^{14}C and ^{63}Ni, since no other instrument will efficiently detect these radionuclides. Liquid scintillation counters work for quantifying samples of both beta and medium to high-energy gamma emitters. It is not an adequate primary method of performing contamination surveys for energetic radionuclides, because samples measured consist of wipes of the areas of suspected contamination. If the contamination is not removable, the wipe will not pick it up, and contamination will not be detected. It is also possible for only part of the contamination present to come up on a wipe, not giving an accurate measurement of the contamination present.

A third instrument which may be used to evaluate contamination is the gamma counter. Again, this is used to gather data in samples containing gamma emitting radionuclides, but for the same reasons as the liquid scintillation counter, it is not a good radiation survey instrument if fixed contamination may be a concern.

Ion chambers are used commonly by the Radiation Safety staff and in locations where frequent and higher flux external radiation hazards are present; they are typically not used for contamination surveys by laboratory staff. These instruments measure the ions produced in air (of one sign) by gamma radiation and are a good indicator of radiation exposure fields. They are useful for exposure readings on shipments, drums of waste at the Radioactive Waste Building, packages prior to shipment and sources and stocks of radioactive materials.

Other more sophisticated instruments used to detect and quantify radiation are the gamma spectrometer or multi-channel analyzer, neutron detectors, alpha detectors, and a wide array of electronic dosimeters, area monitors, and even portal monitors (which a person walks through to detect any contamination on the body or clothing; these are used at nuclear power plants).

For effective and accurate data gathering in radiation, follow a few simple guidelines:

1. Survey at the proper geometry. Hold the detector about 1 cm. or 1/2 inch above the surfaces monitored. If the detector is too far away, serious underestimation of activity or no detection of contamination present may occur. If the detector is too close, contamination of the detector may occur.

2. Use the correct detector. Do not survey for beta or high-energy gamma radiation with a low-energy gamma probe, or for low-energy gamma radiation with a beta probe. NO COMMON LABORATORY SURVEY INSTRUMENT WILL EFFECIENTLY DETECT TRITIUM, ^{63}Ni OR ^{14}C; LIQUID SCINTILLATION TECHNIQUES MUST BE UTILIZED.

3. Survey slowly; do not race the detector over the surface or wave it like a magic wand; the sensitivity of the detection instrument is inversely proportional to increasing survey speed.

4. Do not cover the detector while surveying; covers decrease or eliminate detection, since they act as a shield.

7.8 Instrument Calibration

Radiation detection instruments used for contamination surveys must be operable and capable of detecting the radioisotopes used in the laboratory. To assure this, survey meters will be calibrated annually by the OEHS. Calibrations are conducted using a set of sealed radiation check sources containing known amounts of activity. The percentage of the known activity that the instrument detects is known as the efficiency of the instrument. The sources are for a range of radiation energies; instruments calibrated then can be evaluated as to their performance and accuracy through the calibration.

After calibrating the instrument, a report of the results will be sent to the principal investigator, who should then place the report in the radiation safety record book maintained in the laboratory. Instrument background, efficiencies for various appropriate nuclides used in the laboratory, and comments are on the record. This information is to be used by laboratory staff when surveying for radioactive contamination in the work area.

Instruments will be calibrated upon request and must be recalibrated after repair.

7.9 Contamination Surveys

Radiation safety surveys must be conducted after each use of radioactive materials, and monthly in each laboratory where radioactive materials are stored. Appropriate detection equipment must be used for each radionuclide monitored. Examples are as follows:

^{3}H	Beta	0.018MeV	Liquid Scintillation Counter (Wipe/Smear Samples)
^{14}C	Beta	0.156MeV	Liquid Scintillation Counter (Wipe/Smear Samples)
^{35}S	Beta	0.168MeV	Survey Meter with Beta Pancake G-M Probe
^{33}P	Beta	0.228MeV	Survey Meter with Beta Pancake G-M Probe
^{32}P	Beta	1.71MeV	Survey Meter with Beta Pancake G-M Probe
^{125}I	Gamma	0.035MeV	Survey Meter with Low Energy Gamma Probe
^{51}Cr	Gamma	0.320 MeV	Survey Meter with Beta Pancake G-M Probe

1. Use a survey meter rather than liquid scintillation counter for monitoring all nuclides except ^{3}H, ^{14}C and ^{63}Ni. Survey meters detect both removable and non-removable contamination, whereas wipes and liquid scintillation counting detect only removable contamination. ^{3}H cannot be detected by a common survey meter, so liquid scintillation counting is the only method to conduct a survey for that radionuclide.

2. You must survey in all areas where radioisotopes are used and the adjacent floor immediately after use. In addition to this after-use survey you MUST perform a contamination survey on a monthly basis in all places where radioisotopes are used, stored or disposed, and the floors adjacent to those areas. This monthly survey must include a minimum of ten (10) identified locations of survey. This includes hoods, centrifuges, incubators, cold rooms, sealing equipment, pipetters and any other equipment which has been used for radioisotope work.

3. Make a record of all laboratory surveys. These records must include the following: Completed Room Diagram Form (appendix M) with labels identifying every bench, floor, hood, sink, waste, or other equipment used for radioactive use; the original Use and After-use Survey Log provided by OEHS upon material delivery; and the Monthly Contamination Survey Form (appendix N). For questions, comments or a completed example of these records contact Health Physics. Contamination results include area of contamination, nuclide, DPM reading, uCi amount and corrective action taken. To convert CPM to uCi, the following equation should be used:

CPM / Efficiency = DPM   DPM / 2.22 E 6 = uCi amount

4. To monitor for ^{3}H and ^{14}C, wipes of the area must be taken. Follow these steps:

   a. Use a cotton tip applicator dipped in methanol or water to wipe the work area being checked. You may wipe a large area, then count. If you find contamination, take wipes of smaller areas until you localize the contamination.

   b. Place the cotton tip applicator in a liquid scintillation vial.
   c. Add 10 -15 ml. of counting cocktail.
   d. Let the sample absorb for 30 minutes.
   e. Count in a liquid scintillation counter for 1 minute.
   f. Record the results on the appropriate laboratory survey record form.

5. To monitor all other radioisotopes, use a survey meter with the correct probe. Follow these steps:

   a. Turn the meter on and first check the batteries by looking at the battery check reading. If the batteries are low, replace them before surveying. You may survey with the audio on or off. However, significant rate changes are easily detected by the audio.

   b. Set the meter to read on the lowest possible setting, e.g., **.1X or 1X** the count rate. Set the response to fast response.

   c. Check and record the background reading. (Note: Fast response mode gives a background range, which is needed to determine when contamination is present.)

   d. Slowly scan the area to be surveyed with the probe. Hold the probe about half an inch above the areas to maximize detection.

   e. If the needle reads above twice (rule of thumb for surveying) background, switch the response to slow response to accurately quantify the contamination. Check the suspected source of contamination from more than one direction to confirm the source of the response. The meter response may be due to waste, samples or other radioactive materials in the area, not to contamination.

   f. Record the results of the survey on the appropriate record form.

   g. Decontaminate or dispose of the contamination in the radioactive waste. If the contaminated area or equipment cannot be decontaminated, shield and label the contamination with the nuclide, date and activity in DPM or uCi.

   h. Remember to turn the meter off after each use to save batteries.

i. If major contamination is found, report immediately to the principal investigator.

SURVEY FREQUENCY GUIDE

Situation	Documented Survey Frequency
Radioisotope used in experiment	After each use AND at least monthly
Radioisotope not used in experiment	At least monthly
No Radioisotopes in storage	None

Please understand checking for contamination with the survey meter and/or wipe tests must be done after each use of the material.

The OEHS will make independent surveys of all active radioisotope labs at least annually. The safety audits performed by the Health Physics staff are designed to emulate inspections performed by Federal and State regulatory agencies. These audits are not intended to be intrusive or onerous but must be at least as rigorous as an inspection by an agent of a regulatory agency. Inventory assessment, contamination control, personnel monitoring, training and waste disposal practices will be addressed during these surveys, and the intent is assisting the Approval Holder by finding and correcting safety hazards and regulatory deficiencies.

Copies of the results of surveys will be forwarded to the principal investigator, and a recheck may be conducted in the event corrective action is required. A response detailing the actions to correct the incompliance of the laboratory must be provided by the PI to OEHS. Failure to address the audit results sufficiently and timely may result in a restriction from ordering radioactive material for thirty (30) days. The WSU Radiation Safety Committee may accompany the OEHS on surveys as deemed necessary for problem laboratories or for purposes of auditing the radiation safety program.

Surveys are to be conducted by the project investigator or his/her designee in conjunction with the OEHS surveys. Each lab that is in possession of radioisotopes must conduct contamination surveys monthly regardless of how (in)frequently the materials have been used. The monthly contamination survey does not replace the required after-use contamination survey, nor does the after-use contamination survey replace the monthly survey. Records of these surveys must be kept on the required forms and maintained for review, even if no contamination was found.

When removable radioactivity is found, the area must be decontaminated and then re-surveyed and documented. Detectable levels of removable contamination should be removed, and non-removable contamination should be labeled and shielded whenever possible to maintain ALARA limits.

It is understood that certain areas may be routinely contaminated, such as internal parts of equipment and the inside areas of glassware, and that it may not be practical to decontaminate these surfaces. If this occurs, signs must be posted, and protective clothing and gloves should be used when in contact with these areas. In some cases, such as ^{32}P contaminated equipment, shielding is required.

The limit for removable contamination is 220 dpm, or 50 counts above background for fixed contamination. Radioactive contamination found at or above these levels must be decontaminated or shielded and labeled. (Therefore, one of the advantages of using disposable lab paper on the benches is that one only has to dispose of the contaminated area of the paper in the radioactive waste, rather than decontaminating or shielding.)

Most of the radioisotope use areas on campus are treated as restricted areas and are characterized as locations with controlled access and have proper radiation safety controls in place. **Contamination limits for surveys are the controlled and unrestricted area limits, due to the ALARA programs required of licensees**. **Remember that the ALARA requirement must be adhered to in the above limits, meaning 10% of the limits, where possible.** (For some radionuclides, it is impossible to achieve less than the contamination limits since the instrumentation and normal backgrounds prevent any increased sensitivity. For others, sensitivity may exist where it is realistic to achieve 10% of the contamination limits.)

7.10 Repair, Maintenance or Removal of Equipment from a Radioactive Material Laboratory

Once used for work with radioactive material, equipment shall not be used for non-radioactive work or removed from the posted Radioactive Material work area until demonstrated to be free of residual contamination. Equipment to be serviced by Wayne State personnel or commercial service contractors shall be demonstrated to be free of contamination prior to servicing. If it becomes necessary to make emergency repairs on contaminated equipment, the Health Physicist must be on-site prior to the start of repair work and will ensure that appropriate safeguards are in place. It is the responsibility of the Approval Holder to make sure the Health Physics staff is consulted prior to any repair or maintenance service on contaminated equipment.

7.11 Vacuum Pumps and Hoses Used with Radioactive Material

Vacuum lines and pumps are particularly vulnerable to radioactive contamination. Vacuum lines and pumps used with radioactive material must be appropriately labeled as potentially contaminated. Used lines should be disposed of as radioactive waste, and pump oil should be surveyed frequently for contamination – especially if tritium is used. Used pump oil must be surveyed for contamination prior to disposal and must be disposed of as radioactive waste if contamination is found.

7.12 Leak Tests of Sealed Sources

Each sealed source containing licensed material (other than tritium) with a half-life greater than thirty days, and in any form other than gas, shall be periodically tested for leakage. The test shall be capable of detecting 0.005 uCi. Sources are exempt from testing if they contain <10 uCi of an alpha emitting material or <100 uCi of a beta or gamma emitting radionuclide.

Sources that are being stored and not being used must be tested at least once every ten years, with the exception of alpha emitting sources. Alpha emitting sources must be tested every quarter, regardless of use.

A stored source is one that has not been used for six months and will not be used in the coming six months. It must be removed from its functional position (i.e., electron capture devices removed from gas chromatographs) and secured. Stored sealed sources must be leak tested before being returned to service. The broad license requires that sealed beta or gamma emitting sources are leak tested every six months. Alpha emitting sealed sources must be leak tested every three months.

Principal investigators must have approvals to possess and use sealed radioactive sources. Users must have training, sources must be labeled, and security must be in place. It is the principal investigator's responsibility to assure that the sources are used according to the laws and regulations pertaining to the source. In particular, the leak tests must be performed by the required deadline. If compliance issues are found with sealed sources, sanctions may be imposed.

7.13 Ordering Radioactive Materials

Any receipt of radioactive materials must be authorized by the OEHS. Authorization is based on prior approval by the Radiation Safety Committee as described earlier. All requisitions should be sent to the purchasing department directly via WayneBuy, coding it as radioactive and shipment to the OEHS/Radiation Safety 5425 Woodward Avenue, Suite 300, Detroit, MI 48202. When completing the online requisition use the authorized PI's name. Specify the radioactive material, activity and chemical form. You must specify the name of the person preparing the order and be sure to identify that it is **"Radioactive Material"** that you are ordering. You may set up a standing order with a company. This means you request a PO for a period of time and during that period only have to contact OEHS/Health Physics to let us know you are using the PO and we will give you a confirmation number. We need to know of any radioactive materials coming onto campus. **The laboratory must call OEHS prior to placing the call to the company for request of shipment on the standing PO number.** Every shipment of radioactive material received must be inventoried.

Anyone wishing to bring any form of radioactive material or radiation-generating machine to Wayne State University must obtain the written permission of the Radiation Safety Officer BEFORE the material or machine is brought on to campus. This is to prevent an individual principal investigator or the campus from exceeding the given individual approval or WSU license limits. Members of the Health Physics staff perform frequent physical inventories of radioactive material on campus. Approved users in possession of unauthorized radioactive material risk the confiscation of their entire radioactive material inventory and the termination of their privilege to use radioactive material at the University.

7.14 Receiving and Monitoring Radioisotope Shipments

Shipments of radioactive materials must be delivered directly to the OEHS. The shipping boxes and outer pigs are monitored for contamination by the Health Physics staff, and the survey records are maintained for review. The inner stock vial must be surveyed for contamination by the receiving laboratory within three hours of receipt. This survey must be performed as a swipe-test for contamination, processed through a liquid scintillation counter or gamma counter (as appropriate). The record of this contamination survey must be available for inspection in the laboratory Radiation Safety Logbook.**The radioactive labels on the shipment boxes and lead pigs must be obliterated or removed prior to disposal.**

7.15 Transfer of Radioactive Materials

Transfer of radioactive material between investigators of different projects must be reported to the Radiation Safety Officer prior to the transfer. These transfers must be between committee approved principal investigators, and within the limits of the approved quantities. The transfer should not take place until the authorization has been given by the Radiation Safety Officer.

It is required that we document any transfers of radioactive materials by reassigning the material in our inventory database. To transfer material, call the OEHS and supply the information to the Health Physics staff, who will confirm approval to transfer the material and document the inventory change. Complete the online form found on the OEHS website to document the transfer and supply the necessary information such as monitoring and wipe test results.

Radioactive materials must never be transferred to individuals who have not been approved by the Radiation Safety Committee.

7.16 <u>"Gifts" of Radioisotopes and Radiation Generating Machines</u>

Any person who wishes to accept a donation of radioactive material or a radiation generating machine must first receive written authorization from the Radiation Safety Committee and the Radiation Safety Officer. This requirement also applies to those who wish to transfer their radioactive material or radiation generating machines from another institution. Please be aware that something which starts out being "free" may eventually cost the University several thousand dollars to dispose of (which is usually why it was offered for donation in the first place). Individuals found to be in possession of unauthorized sources of ionizing radiation will have the material / machine confiscated and will be responsible for the full cost of disposal.

7.17 <u>Security and Storage of Radioactive Materials</u>

It is required by U.S. Nuclear Regulatory Commission law that security of radioactive materials must be in place at all times. Violations of this regulation are frequently cited at institutions utilizing radioactive materials and place the license to use such materials in jeopardy. The Code of Federal Regulations, Title 10, Part 20.1801 and 20.1802, Storage and Control of Licensed Materials in Unrestricted Areas, reads:

(a) The licensee shall secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas.
(b) The licensee shall control and maintain constant surveillance of licensed material that is in a controlled or unrestricted area and that is not in storage.

This means that all locations where radioactive materials are present must be in constant attendance by the trained user, or otherwise locked or secured to prevent unauthorized removal or tampering. **Any loss of radioactive materials must be reported to the WSU Radiation Safety Officer immediatel**y.

The personnel present in the laboratory may provide security for radioactive materials by challenging unauthorized entry into the room. Staff members who are not radiation workers may be among those in immediate control of the materials if they are trained by the principal investigator according to the items on the PI Training Checklist (appendix L).

Storage of radioactive materials shall be in secured or locked cabinets, refrigerators, freezers or waste areas, unless attended by the licensee. Radioactive materials shall be stored in sealed containers in such a way as to prevent accidental spillage or breakage, and to prevent release into the air. If the nuclide requires shielding, it shall be stored in shielded containers to prevent doses to personnel accessing the storage areas.

If the radioactive material has been stored in a freezer or ultra freezer, it is imperative that the material be thawed, opened and handled in a certified fume hood. Aerosols from stored radioactive materials may cause contamination of adjacent areas and doses to personnel if not handled in the proper way after storage.

All radioactive materials, whether in storage, waste or use, must be labeled with the radioactive warning symbol, the words "Caution, Radioactive Materials", the isotope, the date and the amount of radioactivity in DPM or microcuries.

7.18 Inventory of Radioactive Materials

The NRC requires that all licensees maintain records tracking the receipt, use and disposal of radioactive materials. This is done with an inventory maintained in a database at the OEHS. Shipments of radioactive materials are logged into the database for each principal investigator ordering the material. Additionally, workers using the material, training dates, locations where material is used, monitoring equipment and radioisotope approvals are maintained in the database. Periodically, a printout of information for a project leader will be sent to the laboratory, and information must be updated and corrections made. This information is a legal record subject to inspection by any regulatory agency; efforts must be made to keep records as accurate and complete as possible to prevent NRC violations.
Use logs are required in laboratories for all radionuclides. The log is provided by OEHS to the lab upon delivery of each shipment of material and must contain records of amounts used, who used them and dates of use. These records must be kept on the **original** Use log and After-use Survey Form provided; if additional space is needed a blank copy of the form is available in appendix O of this manual.

7.19 Shipment of Radioactive Materials

Shipments of radioactive materials leaving the University must have prior authorization of the Radiation Safety Officers at both the sending and the receiving institutions. Federal and State law requires that the shipper must obtain the receiver's approval and the respective Nuclear Regulatory License number or the State License number prior to the shipment of the material.

All shipments must be in accordance with the packaging and labeling requirements set forth by the Department of Transportation (DOT); an appropriate record must be made of the radiation levels on contact with the package and at three feet from the package using an ion chamber. Also, the record must contain information on the shipper, receiver, nuclide(s) and activity, phone numbers of shipper and receiver, and performance of a survey for removable radioactivity. **Contact the Radiation Safety Officer or the Health Physics Specialist well in advance of the desired shipping date to assure that all the required license exchanges, shipping papers and monitoring records are completed, as the package will not be shipped until these requirements are met.**

7.20 Disposal of Radioactive Waste

Due to the problems in radioactive waste management and legal requirements, no radioactive waste may be removed from a laboratory without proper packaging, proof of a contamination survey and complete information on the waste tag. Chronic failure to thoroughly prepare radioactive waste for removal and transport may result in suspension of permission to use radioactive materials.

1. Read and understand the Wayne State University Hazardous Waste Disposal Manual/Guide. This document should be located in your laboratory and is available for printing on the OEHS website.

2. Make requests for waste containers, tags, or removal on the OEHS website at http://www.oehs.wayne.edu.

3. Before you begin to use the containers in your lab, Complete the top portion of the waste tag. This information identifies your laboratory, including room number, building name, phone number, principal investigator and the isotope to be disposed.

4. You must separate all radionuclides into separate containers. If your protocol requires the use of two or more nuclides that are inseparable for disposal, please contact Health Physics.

5. You must separate the solids and the liquids. Under no circumstance should liquids be placed in the solid waste or solid material placed in the liquid waste. Items must have all free liquid removed prior to being placed in the solid waste container. Stock vials and "pigs" may be opened and placed directly in the dry waste.

6. You must have secondary containment for your liquid radioactive waste container(s), in case of a leak, spillage, or rupture of the container.

7. Record the isotope, activity, date and initials every time material is added to the waste container(s). Each pair of gloves or pipette tip need not be manifested, but there should be an entry for each experiment or day that material is added.
8. Be sure to list the chemical components of the liquid waste in the space provided on the waste tag. Put the chemical name followed by the percent by volume or other units to quantify that chemical. Chemical names must be fully written out; chemical formulas are not acceptable. This helps the OEHS determine how to package and dispose of the waste.

9. Fill the liquid container(s) no more than 3/4 full. Overfilling the containers presents a hazard to the lab workers and OEHS personnel. When the container is ready for disposal, go to our website to request a pickup. Please complete the online form for each solid, liquid, animal or vial waste item you want picked up, and put the isotope and activity for each container.

10. Mixed waste (waste that is both radioactive and chemically hazardous), must be disposed of within 90 days of filling in accordance with the Environmental Protection Agency and the Department of Natural Resources regulations. This includes scintillation vial waste that contains flammable cocktail or liquids that contain more than 15% of a hazardous chemical waste. (We will be glad to help you determine whether your liquid waste is classified as a mixed waste.)

Note: Waste items that are overfilled, contaminated on the outside, have incomplete tag information or are improperly packaged will not be picked up until the problem is corrected.

The OEHS has developed the Wayne State University Waste Disposal Guide, which describes the requirements and specific procedures for correctly managing and disposing of radioactive, chemical, biological and pathogenic waste. Please use this guide when preparing waste for disposal. All radioactive waste shall be separated from non-radioactive waste. **Under no circumstances is it permissible to dispose of any radioactive material into the non-radioactive trash or into any drains.**

The issue of radioactive waste disposal is very complex, due not only to the radioactive nature of the waste and its inherent disposal problems, but also the recent concerns with the chemical hazards associated with the same waste. Hence, it is possible to have mixed waste, which contains not only radioactive waste, but RCRA (Resource Conservation and Recovery Act) hazardous chemical waste. Liquid scintillation vials are an example, because the toluene is hazardous under the RCRA laws, due to flammability. Radioactive waste must be properly manifested for the isotope and activity, and any other hazardous constituents, including chemical or biohazardous components. Complete waste disposal instructions may be found in the Wayne State University Waste Disposal Guide.

Radioactive waste must be completely labeled at all times, from the time it is deposited into a container until final disposal. Records of radioactive waste disposal must be maintained by the University for NRC review, so this labeling or "manifesting" is critical. Tags must have, at a minimum, the Approval Holder's name and the waste radionuclide(s) listed at all times after any radioactive waste is placed in the container. (Note: The radiation warning label and certain other information on the tag must be present according to NRC regulation.)

The OEHS supplies the solid and liquid waste containers to laboratories upon request. It is the responsibility of the laboratory to supply secondary containers, such as a plastic bus tray, to prevent the waste from leaking or contaminating work surfaces. Laboratories must supply their own shielding for waste that may cause external exposures to workers in the area.

Bench top waste containers are considered part of the experiment and must be labeled with the isotope information and a Caution: Radioactive Material label. It is not necessary to attach a waste tag until the waste is placed in the permanent waste container.
To dispose of waste under the current regulatory constraints, it is necessary to segregate all radioisotopes and to segregate chemically hazardous waste from other radioactive waste.

Radioactive waste may cost as much as several hundred dollars per cubic foot to dispose of. Therefore, it is prudent that workers only place waste which is contaminated with radiation in the radioactive waste containers. This can be achieved by carefully monitoring potential radioactive waste with an appropriate survey meter prior to disposal. If there is reason to believe that a waste item may be contaminated with a low-energy beta emitter that can not be detected with a survey meter, it is better to dispose of it as radioactive waste than risk sending radioactive material to the municipal landfill.

The License issued by the Nuclear Regulatory Commission allows the University to minimize radioactive waste disposal costs by storing short-lived radioactive waste for decay. Waste that has been decayed-in-storage and found by survey to be at background levels may be disposed of as non-radioactive waste. Short-lived material is defined as any radionuclide with a half-life of less than or equal to 120 days. Approval Holders should ensure that their workers know to which category the radioisotopes used in their lab belong. Lab using short lived Pet Tracers may dispose of their radioactive waste as regular trash provided they complete the *Decay in Storage Worksheet* and retain the documents for inspection. **These special circumstances must be discussed with the Health Physics personal prior to starting this procedure.** There can be not radiation symbols on the waste and all waste must be decayed to background.

SHORT-LIVED RADIOISOTOPES include ^{32}P, ^{33}P, ^{35}S, ^{86}Rb, ^{51}Cr, ^{125}I, and ^{73}As. These and other radionuclides with half-lives less-than or equal-to 120 days may be stored by OEHS for decay.
LONG-LIVED RADIOISOTOPES include ^{3}H, ^{14}C, ^{45}Ca, ^{65}Zn, ^{125}Sn, ^{109}Cd, and ^{63}Ni. These and other radionuclides with half-lives greater than 120 days need to be disposed of by OEHS soon after they are removed from the lab.

A radioactive waste pickup should be requested when a container is ¾ full. Prior to submitting a waste pickup request, the waste containers must be sealed, all appropriate forms, tags and labels must already be filled out and attached to the container, and the container must be wipe surveyed for removable contamination.

7.21 Quantifying Levels of Radioactivity in Waste

Radioactive and other hazardous materials must be completely manifested for waste transport and disposal. To accurately list levels of radioactivity on the tags, it is necessary to assess the levels which are disposed in both liquid and solid waste. Suggestions on methods to quantify the waste follow.

1. During a given experiment it is known that a certain quantity of radionuclide is used. At the end of each of several similar experiments, take a sample of liquid waste and count it with the appropriate counting equipment. The activity in the sample per unit volume is then multiplied by the total volume of the liquid waste generated. For the solid waste, the quantity of radioactivity in the liquid is subtracted from the total quantity used in the experiment, and the remainder is then the quantity in the solid waste.

   Example:

   Total Used in experiment: 500 uCi
   Liquid Sample Volume: 1 ml
   Total Liquid Waste Volume: 4000 ml
   Activity in Liquid Waste Sample: $8X10^{-2}$ uCi/ml

   Liquid Waste Total Activity: $8X10^{-2}$ uCi/ml X 4000 ml. = 320 uCi in liquid waste
   Solid Waste Total Activity: 500 uCi - 320 uCi = 180 uCi in solid waste

2. After the first few experiments, or when the waste carboy is full, take a sample of the pooled liquid waste, and count it as above. Multiply the activity of the sample per unit volume by the total volume in the carboy to obtain the total activity in the carboy. Quantify the solid waste as above by subtracting the liquid waste activity.

3. If direct counting of your radioactive waste is not practical, a good rule-of-thumb for the estimation of activity is:
   80% of waste activity is in the liquid component.
   15% of waste activity is in the dry solid component.
   5% of the waste activity is in scintillation vials.

   These percentages will vary with the experimental procedure but should serve as a good starting point for the estimation of radioactive waste activity.

7.22 ALARA

ALARA is an acronym meaning **As Low As Reasonably Achievabl**e. It is a requirement in the law, meaning all facilities possessing radioactive materials licenses must have a formal ALARA program. It may be defined as a professional standard of excellence, and is practiced by keeping all doses, releases, contamination and other risks as low as reasonably achievable. The regulatory guideline and our license require managing programs and procedures to achieve □□10% of applicable legal limits, such as air and water release limits, exposure limits or contamination limits for radiation use facilities.

Wayne State University has the ALARA concept written into the NRC Material License, with the goal to incur no exposures, releases or contamination. Since this is generally not feasible or practical in radiation use facilities, WSU has adopted 10% of the legal limits as the action level for exposures, releases and contamination control.

It is not a violation of the law to exceed an ALARA guideline; however, these occurrences alert radiation safety staff and radioactive materials users to situations which need to be reviewed to determine whether the practices may be modified to better reflect ALARA management practices. Practical measures to incorporate ALARA into work practices are included in this manual to assist radiation workers. Some simple concepts and easy precautions may prevent contamination, exposures and releases.

7.23 Keeping Exposure ALARA

Minimizing the amounts of radioactive materials handled in all cases will reduce exposure potential, since exposure is directly related to the amount used and how it is handled.

The three routes of entry into the body for radioactive materials are **inhalation**, **ingestion** and **skin contact (absorption/injection**). Precautions should be taken to avoid each of these means of internal exposure to radiation.

External radiation exposure is possible with certain kinds of radiation. Methods of minimizing this potential are **time**, **distance**, **shielding and minimizing the amount used**. Precautionary measures are discussed further in the following sections.

7.24 Time, Distance and Shielding

Three primary means of eliminating or reducing radiation exposures exist. They are:

Time:
Minimize the time that radioactive materials are handled. Since the amount of exposure occurs as a function of duration of exposure, less time means less exposure. This may be achieved by conducting "dry runs" (practicing the procedures to be performed, with all of the steps and manipulations performed without the hazardous materials). Familiarity with the experimental protocol allows the work to be performed quickly and efficiently, while minimizing the potential for mishaps due to poor planning and setup.

Distance:
Maximize the distance from the radioactive materials. Dose is inversely proportional to distance; therefore, greater distance means less dose. Do not increase the distance to the point wherein dexterity or control of the materials is jeopardized.

Shielding:

Use shielding wherever it is necessary to reduce or eliminate exposure. By placing an appropriate shield between the radioactive source and the worker, radiation is attenuated and exposure may be completely eliminated or reduced significantly. The type and amount of shielding needed to achieve a safe working level varies with the type and quantity of radioactive material used. For isotope shielding information consult appendices C through K. The HVL (half-value layer) may be used as a guide to the thickness of the shielding necessary to block the radiation. The HVL is the thickness of the shielding necessary to reduce the radiation dose rate to half of the original or unshielded dose rate. Refer to the HVL information in the appendices on specific nuclides.

7.25 Protective Equipment

In order to prevent contamination of skin, eyes or personal apparel, protective equipment should be utilized during use of radioactive material. The specific types of protective equipment needed are dictated by the nuclide, level of activity, chemical form and experimental procedures.

Two main categories of protective equipment are personal protective equipment and engineering controls. Personal protective equipment is protective equipment worn by the worker. Examples are gloves, laboratory coats and safety glasses. Engineering controls are external equipment designed to protect the worker or are a part of the design of the work area. Examples are fume hoods, biological safety cabinets, building ventilation systems and shields.

Individuals using radioactive materials must wear laboratory coats, gloves and eye protection. Additional protective equipment may be necessary or prudent. Contact a Health Physics Specialist if you have questions about protective equipment.

7.26 Personnel Monitoring

Radiation detection dosimeters (badges) must be worn routinely by personnel when exposure to penetrating radiation is possible. At Wayne State University, this means that workers handling radiation that is energetic enough to expose live cells are required to wear a dosimeter. Dosimeters are exchanged quarterly, and in some locations, monthly. Each individual is responsible for seeing that his/her badge has the current dosimeter within the holder.

These badges provide legal documentation of external radiation exposure received while working with radioactive materials at a given facility. They are not to leave your immediate work area; they are not to be taken home or to any other location, since non-occupational exposures may occur (e.g., a dentist's office or another laboratory). Badges are heat and light sensitive, and if left in a car where the temperature may be high, a false exposure will be recorded. It will then become difficult to distinguish a true radiation dose from a dose caused by exposure to excessive heat or light.

Radiation detection dosimeters are not assigned for work with certain radionuclides since the energies are beneath the detection limit of the badge. This is not a risk to the worker, however, because these kinds of radiation are not penetrating enough to cause a deep radiation dose. Examples of these radionuclides are ^{3}H, ^{14}C, ^{35}S, ^{45}Ca, ^{33}P and ^{63}Ni.

For those individuals who use x-ray equipment and/or high energy beta or gamma emitters, extremity (ring) badges should be used in conjunction with the whole-body dosimeter. **It is a legal requirement that workers handling 1 mCi of ^{32}P must wear extremity badges.** The whole-body badge should be worn on the torso with the name tag facing the suspected source of radiation. With finger ring badges, the name tag must face the radiation source, or typically the palm of the hand.

Care should be taken to make sure that badges do not become contaminated with radioactive materials. Lost or misplaced badges should be reported immediately to the OEHS in order to receive a replacement. Under no circumstances should workers wear a dosimeter belonging to another individual. It is a legal requirement that doses be tracked for the worker to whom the dosimeter is assigned.

When terminating employment with the University, badges must be returned to the OEHS. If badges are not returned and proper notification of termination of employment/study has not occurred, it is a violation of regulatory requirements. A termination report will be supplied when a worker leaves, since the next place of employment must be supplied with this report before the individual will be allowed to work with radioactive materials.

It is important to return your badge at the proper time. Delays in processing and reading the badge may invalidate the results. Chances of the badge being lost are increased with late badge returns.

At any time, individuals can contact the OEHS for their dosimeter data. It typically takes 4 to 6 weeks to have the badges sent off and processed. The badge vendor will call the OEHS to report any doses that are significantly higher than normal (i.e., greater than 200 mrem on a badge) and the worker will be notified by a Health Physics Specialist. **If you suspect that you have received a significant exposure, contact the Radiation Safety Officer immediatel**y. Potential exposure will be evaluated, and the badge may be sent immediately for an emergency reading. A spare badge will be issued for the interim period. Results can be obtained within a few days with emergency processing. For more information, please refer to the University's Dosimetry Policy in Appendix X.

7.27 <u>Bioassays</u>

A condition of the broad license issued by the Nuclear Regulatory Commission (NRC) mandates that bioassays are required for workers using certain types and amounts of radioisotopes.

Individuals performing or observing iodination where one millicurie or more of ^{125}I is used are required to obtain a thyroid scan after the iodination. A baseline thyroid scan should be conducted on workers who have not previously used these kinds of ^{125}I at Wayne State University. Individuals must receive a thyroid scan bioassay with the OEHS between 6 and 72 hours after each iodination or use of millicurie quantities of free radioiodine.

Individuals handling or observing the use of 100 mCi or more of tritium (^{3}H) must submit a urine sample to the OEHS for bioassay before use as a baseline, and after use, within 24 hours of the experiment. A urine sample must be submitted after each subsequent use of 100 mCi or more. Contact the Health Physicist for further details concerning urine bioassays.

Individuals handling or observing the use of 10 mCi or more of ^{32}P must submit a urine sample to the OEHS for bioassay between 12 and 48 hours after use. A urine sample must be submitted after each use of 10 mCi or more. Contact the Health Physicist for further details concerning urine bioassays.

Urine samples are only collected to evaluate internal radiation exposure and are not used for any other purpose. If there appears to be a likelihood that a significant internal exposure has occurred, the Radiation Safety Officer may require further bioassays as deemed necessary.

7.28 Minors Working with Radioactive Materials

Radiation exposure limits exist for minors, (individuals under 18 years of age) who work with radioactive materials. These limits are 10% of all of the occupational limits for adult radiation workers. For these workers, safety training must be completed prior to work with radioactive materials as with other occupational workers. It is University policy that an informed parental consent form must be completed and kept on file for purposes of liability and risk management.

Due to University policy and legal requirements, principal investigators must notify the OEHS and obtain the permission of University Legal Counsel before allowing minors to handle radioactive materials. Please view the policy regarding minor in labs on the OEHS website, http://research.wayne.edu/oehs/lab-safety/index.php.

7.29 Pregnant Radiation Workers

A special situation arises when a radiation worker becomes pregnant. Under these conditions, radiation exposure could also involve exposure to the embryo or fetus. A number of studies have indicated that the embryo or fetus is more sensitive than the adult, particularly during the first four months of pregnancy. This can be a problem since many workers are unaware of their pregnancy during the first month or two of gestation. Hence, the NRC and the State of Michigan require that all occupationally exposed workers be instructed concerning the potential health protection problems associated with prenatal radiation exposure.

The maximum permissible exposure for a declared pregnant worker during the gestation period is 500 mrem. There are very few research laboratories at Wayne State University where this high of a radiation dose could occur. If a radiation worker is pregnant, she may notify the Radiation Safety Officer, and then declare the pregnancy in writing for the prenatal exposure limits to take effect. The pregnant radiation worker will then meet with a health physicist, and a complete assessment of her radiation exposure potential will be made. The written declaration is made by completing a Declaration of Pregnancy form, which is maintained in the records by the OEHS.

If the pregnancy is not declared in writing, the radiation exposure limit remains at the normal occupational level of 5 rem per year. An individual may "un-declare" her pregnancy at any time, but this must also be in writing.

Declared pregnant workers (DPW) will be assigned two badges, one for the whole body, normally worn on the torso and one for the fetus, normally worn on the abdomen. The badges will be exchanged monthly. Exposures must be maintained beneath a cap of 50 mrem per month to prevent exposure spikes.

7.30 Exposure Limits for the General Public

Visitors to a radiation laboratory who are not classified as radiation workers by their employers, laboratory workers who are not trained in radiation safety, custodial staff, and any other non-radiation workers are all members of the general public under the law. They must not receive a radiation dose in excess of either:

A. Two mrem in any one hour.
B. 100 mrem in any one year.

Since most radiation use facilities frequently have members of the general public visit their work areas, Wayne State University has elected to maintain unrestricted area contamination limits as part of the ALARA program in order to ensure that public dose is minimized.

7.31 Food and Drink in Radioactive Material Labs

Many of the radioisotopes used at the University do not require shielding but are serious internal radiation hazards. Great care must be taken at all times in radioisotope labs to prevent the inhalation, ingestion or absorption of radioactive material, and strict Federal and State regulations are in place to protect the worker against these hazards. Due to the number of NRC violations cited at academic institutions, including WSU, the WSU Radiation Safety Committee and the Office of the Vice-President for Research and Graduate Studies have adopted a policy regarding food and drink. The following policy must be adhered to by radioisotope principal investigators and users.

Wayne State University Policy for Food and Drink in Laboratories

There shall be no food, drink, smoking or applying cosmetics in the laboratories which have radioactive materials, biohazardous materials or hazardous chemicals present. There shall be no storage, use or disposal of any "consumable" items in laboratories (including refrigerators within laboratories). Rooms which are adjacent, but are separated by floor to ceiling walls, and do not have any chemical, radioactive or biohazardous agents present, may be used for food consumption or preparation at the discretion of the principal investigator responsible for the areas.

It is important to be aware that even the presence of empty food and drink containers in the normal trash may cause a violation since it is construed as "evidence of consumption" by regulators and the burden of proof to the contrary then lies with the licensee. Please also note that gum and tobacco chewing are prohibited in laboratories.

Floor to ceiling enclosures must separate food areas from hazardous materials areas, due to the potential for release of a hazardous material into the air, and then into a food area when only partial barriers are present.

If empty food or drink containers are used for storage or disposal of laboratory waste, pipette tips, or other laboratory equipment, reagents or materials, they must be clearly labeled. If used for disposal of items contaminated with radioactive materials, the containers must be clearly labeled with the radioactive materials warning symbol, and the nuclide, quantity of activity and date. Original labeling must be removed, defaced or destroyed to avoid confusion about the contents of the container.

7.32 Training

It is mandatory that all workers, including principal investigators, be certified prior to the use of radioactive materials. Certification is obtained by attending the introductory OEHS training class and passing the radiation safety examination. All radiation users/handlers, including principal investigators, must attend both the radiation safety and Laboratory Safety training class, since it is impossible to use radioactive materials without also using chemicals routinely or intermittently.

Initial training must contain minimally the items listed in Title 10, Code of Federal Regulations, Part 19.12 (10 CFR 19.12), Training for Radiation Workers. The OEHS offers a training class in radiation safety; this covers the necessary topics. Annual retraining is required for all users of radioactive materials (including principal investigators).

Individuals who frequent areas where radioactive materials are present and radiation workers must be trained by the principal investigator according to the functions performed. This training may be evaluated during inspections, either by discussions with individuals present or by written records, if they are used. A checklist (See PI Training Checklist - Appendix L) has been developed which may be used to assist with the clarity and uniformity of the principal investigator training records.

Registration is required in advance for introductory safety training classes; dates of available training sessions may be obtained by calling the OEHS (577-1200) or visiting the OEHS Web Page, http://research.wayne.edu/oehs/rad-safety/training.php. Advance registration is not required for refresher training, since dates, times and locations are announced in advance, and attendees register during the class.

7.33 Principal Investigator Absences

Principal investigators may be occasionally absent from the laboratory for various reasons. During such absences, another individual must be named to assume the responsibility for the correct usage and management of radioactive materials. When the absence is less than 60 days, a responsible graduate student or technician may be appointed to assume responsibility. If the absence is greater than 60 days, an alternate principal investigator with the appropriate radioisotope approvals must be designated and must agree to assume responsibility.

The OEHS must be notified in writing of the absence duration and the name of the alternate principal investigator who will oversee the uses of radioactive materials during the absence prior to departure. The stand-in PI must have all the authorizations necessary to oversee the uses of the radioactive materials possessed by the absent PI. The OEHS must be notified in advance of the intended absence. During the absence, shipments will still be logged under the absent principal investigator's inventory, but all oversight will be conducted by the stand-in PI.

7.34 Terminating Employment

If a principal investigator terminates employment at Wayne State University, the OEHS shall be notified at least two weeks beforehand. Arrangements must be made to remove or transfer any radioactive materials according to the requirements of the OEHS. Before the termination date, the radiation safety staff will conduct a final radiation survey of the radioisotope laboratory in order to determine the presence of unused radioisotopes and/or the presence of contamination.

Radiation workers who terminate their academic research endeavors, education or employment at the university shall notify the OEHS, and their dosimeters must be returned. Federal law, implemented on January 1, 1994, mandates that new workers who will use radioactive materials must supply the current year exposure report to the safety office prior to beginning work with radioactive materials. Wayne State University maintains dose records for all radiation workers. To meet this requirement at future locations, this information will be supplied to a worker leaving Wayne State University after the assigned dosimeters have been returned to the OEHS.

7.35 <u>Approval to Use Radiation Generating Machines</u>

A Radiation Generating Machine (RGM) may be classified as any device that incidentally or purposefully produces ionizing radiation when energized. RGMs are used at university sites with a great variety of configurations and operating characteristics and in a wide spectrum of applications.

Specific examples of RGMs addressed include but is not limited to: X-ray producing radiography equipment; research and analytical X-ray or electron beam machines; sealed particle accelerators; Van de Graff generators; electromagnetic pulse generators (if capable of producing ionizing radiation); electron microscopes; electron arc welders; microwave cavities that produce X-rays incidentally, and cold cathode ray tubes.

Users of Radiation Generating Machines must apply to and receive approval from the Radiation Safety Committee PRIOR to the purchase and/or receipt and installation of any instrument capable of producing ionizing radiation when energized. The application for approval must include machine-specific radiological information, proposed installation diagrams including interlocks, shielding, and estimated dose rates in surrounding occupied areas, and written procedures for normal operation and use during the proposed experimental procedure.
Radiation producing equipment such as diffractometers, x-ray spectrometers, electron accelerators, diagnostic and therapeutic x-ray machines, and electron microscopes are all regulated by the Michigan Department Industry and Consumer Resources, Radiological Health Division. Equipment of this type must be registered with the State of Michigan. A copy of this registration must be displayed in the room with the radiation producing equipment. Posted information shall also include a copy of Section 5 of the State of Michigan's Ionizing Radiation Rules and form RSS-100 (Notice to Employees). It is required that all work done with these machines will be in accordance with the Ionizing Radiation Rules of the State of Michigan.

<u>Approval Holder Responsibilities</u>

RGM control is the responsibility of the Approval Holder. Oversight for radiological safety is provided by the Radiation Safety Committee and the Radiation Safety Officer. The RGM Approval Holder must provide direct control and oversight of RGM installations and operations. The Approval Holder must ensure that the RGM installation is operated and maintained safely and in accordance with the licensing requirements of the State. Specific responsibilities of the RGM Approval Holder include, but are not limited to, the following:

- controlling the keys to RGM installations, RGMs, and/or RGM storage facilities and authorizing the operation of the RGM installation.

- ensuring that RGM Operators follow applicable operating procedures.

- ensuring that RGM Operators follow the applicable radiological safety rules and regulations.
- ensuring that required dosimeters are properly worn.
- ensuring that inspections of RGM interlocks, warning lights, and other safety features are performed and documented.
- ensuring that all required monitoring is performed and documented.
- ensuring that all RGM Operators are trained.
- reviewing and approving materials used for training RGM Operators, in cooperation with the Health Physics staff.
- ensuring that accountability records of assigned RGMs are maintained.
- notifying the Health Physics staff of changes in shielding configuration, use, storage, disposal, or loss of a RGM.
- ensuring proper disposition of unneeded RGMs
- maintaining schematics (mechanical and electrical), safety device wiring diagrams, manufacturer provided instruction manuals, and operations and maintenance records.

Operator Responsibilities

RGM Operators are those individuals authorized by the RGM Approval Holder to use the RGM.
The RGM Operator must:

- ensure proper control of the RGD installation and/or area.
- ensure that inspections and monitoring are performed and documented.
- ensure that required dosimeters are worn properly by all individuals in the vicinity of RGM operations.
- follow the stipulations of the applicable Approval as issued by the Radiation Safety Committee and ensures that other individuals also adhere to the stated requirements.
- establish control of all adjacent areas where individuals could receive a dose approaching administrative limits and ensure that those areas are unoccupied during RGM operations.
- maintain access control over the actual RGM exposure area.
- follow all applicable operating procedures; and
- promptly terminate unsafe RGM operations.

Radiation Monitoring and Shielding

Radiological monitoring must be conducted to determine and document the integrity and adequacy of the shielding and to verify that posting and access control requirements are satisfactory before the RGM is turned over to the Approval Holder for routine operation, and periodically thereafter. If there is a potential for exposure in accessible areas adjacent to the installation, then the adjacent areas must be monitored and, if required, vacated during machine operation.

Specifically, the pre-operational monitoring program must be designed to:

- determine dose rate or integrated dose received in any 1 hour as dependent upon the pulse capability of the RGM.
- evaluate the exposure potential of the RGM at the maximum value of applied voltage or current. The RGM should be operated in steps of increasing beam strength until the highest values are achieved.
- include the use of mechanical or electrical devices that restrict beam orientation and magnitude, and determine the degree of beam restriction, with and without those devices.
- detect and measure potential leaks in the shielding and barriers; and
- encompass all geometries in which the useful beam can be directed.

Special monitoring must be conducted as follows:

- during the performance of maintenance and alignment procedures if the procedures require the presence of a primary beam.
- when any component in the system is disassembled or removed.
- any time an inspection of the components in the system reveals an abnormal condition.
- whenever personnel monitoring dosimeters or area monitoring show a significant increase over a previous monitoring period or are approaching administrative limits.
- following maintenance or calibration prior to restoration to fully operable status; and
- after any modification.

It is not necessary to perform radiological monitoring of electrically energized RGMs during periods when they have been removed from service and placed in storage. However, when any RGD which has been in "storage" is being reactivated for use, functional and operational inspections and radiological monitoring must be performed prior to initial use.

For open installations, where irradiation configurations and boundary conditions are likely to change frequently, radiation monitoring shall be conducted in response to changing working parameters. Any specific configuration or boundary condition may only be utilized if it has been reviewed and approved by the Radiation Safety Committee.

Health Physics Audits

After the initial assessment, the Health Physics staff will conduct periodic safety inspections and monitoring as necessary to verify that:

1) RGM operations continue to remain safe.
2) During the operation of any open installation, the proper location and posting of boundaries is maintained; and
3) After any modification or removal from storage of a RGM installation, the effectiveness and operability of safety features are adequate

Postings, Warning Lights and Alarms, and Interlock Systems

Posting must be used to signify the presence of an intermittent radiation condition. The posting must also express the method used to convey that a radiation field is present. An example of such a sign is:

"CAUTION: RADIATION BEING PRODUCED OR RADIATION AREA EXISTS WHEN RED LIGHT IS ON"

Federal and State regulations require that measures be taken to maintain radiation exposures in controlled areas ALARA, or As Low As Reasonably Achievable. The primary method used shall be physical design features (e.g., interlocks, shielding); administrative controls shall be incorporated only as supplemental methods and for specific activities where physical design features are demonstrated to be impractical. Regulations also require that during routine operations, the combination of design features and administrative controls shall provide that the anticipated occupational dose to general employees does not exceed regulatory limits and that the ALARA process is utilized for personnel exposures to ionizing radiation.

Physical design features typically include features that are used to control the work environment, such as permanent structures, interlock systems, and controls, shielding, and the use of designs and materials that facilitate operations, maintenance, and other activities. Physical design features may also include engineering controls (e.g., temporary shielding, confinement and ventilation systems) that are typically used to facilitate short-term or emergent operations when the installed physical design features do not provide the desired level of protection.

Administrative controls typically include controls that are implemented by the safety organization at the work site, including written procedures, technical work documents, work authorizations, and other controls that are used to guide individual actions in a manner that will facilitate implementation of the ALARA process.

It is the position of the Radiation Safety Committee that appropriate physical design and engineering controls, in the form of interlock devices, protective barrier cabinets, and shielding shall be the PRIMARY method of ensuring that all exposures are ALARA. Administrative controls, in the form of warning devices, postings and notices, and written safety procedures ARE NOT satisfactory substitutes for design and engineering controls and will only be considered on a case-by-case basis for existing installations with a low hazard potential.

The purpose of access control devices is to prevent unauthorized or inadvertent entry into a radiological area and/or to warn of a hazard. If locked entryways are used, the keys used for one RGM installation or storage facility must not provide access to another RGM installation or storage facility. Additional measures shall be implemented to ensure individuals are not able to gain unauthorized or inadvertent access to very high radiation areas. Such measures (i.e., physical constraints) should include locking or securing service doors and panels with tamper resistant fasteners or the use of multiple and redundant access controls.

Doors and/or access panels in unattended installations must be equipped with one or more fail-safe safety interlocks to prevent irradiation of an individual. If an area radiation monitor is incorporated into a safety interlock system, the circuitry must be such that a failure of the monitor shall either prevent normal access into the area or prevent operation of the RGM.

One or more physical control devices should be used to secure the RGM to prevent unauthorized access and use. The control system governing the production of radiation must be equipped with a lock and key to prevent unauthorized use. The key controlling the production of radiation in one RGM should not control the production in another and must remain in the control of the Approval Holder or his/her authorized Operator at all times.

Control devices used to limit RGM time, position (irradiation geometry), current, voltage, beam intensity, or control panel lights or system indicators must be fail-safe. Failure of any one or more control device must cause the RGM to de-energize.

Procedures must be implemented to ensure that the RGD installation and the RGD safety interlock control devices are such that:

- radiation cannot be produced until the interlock system logic has been completely satisfied.
- production of radiation cannot be resumed by merely reestablishing the interlock circuit at the location where an interlock was tripped; and
- the safety circuit cannot be re-energized or reestablished automatically (i.e., there must be a manual safety circuit reset on or near the main control console).

For each area designated as a high radiation area or very high radiation area, a control device must be in place to automatically generate audible or visible alarm signals to alert individuals and the cognizant RGM Operator of a potential entry into the radiation area before it occurs.

Warning devices must be provided as an addition to any other access control feature in accordance with the installation-specific requirements specified by the State of Michigan and the WSU Radiation Safety Committee. These warning devices are typically warning lights.

All RGM warning lights should be red or magenta for consistency. A sufficient number of lights must be installed so that at least one light is easily visible from all reasonably occupied areas that may have potential for radiological hazard and from reasonable avenues of approach to such areas.

However, warning lights (even though interlocked to fail-safe if burnt out) are only passive in nature. When operating, they generally do not prevent an individual from physical access to a radiation beam unless they are used as part of a photosensitive circuit. Such a circuit would remove the radiation beam or field if any individual intercepted the light beam and provide an acceptable engineering control.

It should not be possible to override the operation of any warning device activated by a fail-safe function without positive actions by the operator such as resetting controls at the control console.

Safety interlocks are not to be used for routine activation and deactivation of the RGM. Interlocking devices may only by-passed or disabled with the written permission of the Chair of the Radiation Safety Committee. Any RGM found to be operating with safety interlocks that have been disabled without the permission of the Radiation Safety Committee will be immediately locked-out by the Radiation Safety Officer and the associated Approval to Use Ionizing Radiation will be revoked.

Any time an installation requires maintenance, the entrance to the area in which the installation is located and the inside of the installation should be conspicuously posted to indicate the maintenance status of the installation. Posting should be established:

- during the performance of maintenance and alignment procedures if the procedures require the presence of radiation; and

- any time an inspection or monitoring reveals a deficient condition for any safety device.

When a safety device or interlock has been approved to be by-passed or is awaiting repair, the entrance to the installation and the RGM enclosure should be posted with a prominent sign bearing the words "SAFETY DEVICE NOT FUNCTIONING" or a similar message.

Accelerators, Electron Devices, and Sources of Incidental Radiation

Accelerators used for radiography, ion implantation, or the production of incidental photons or particles must be operated in accordance with applicable Federal and State regulations and are subject to the same oversight by the Radiation Safety Committee as other RGMs.

Electron devices that generate incidental x-rays include electron beam welders, electron microscopes, pulse generators, and microwave cavities used as beam guides. Preoperational inspections and monitoring should be performed initially upon receipt. However, the requirement
for the routine semiannual inspections and monitoring may be modified at the discretion of the Radiation Safety Committee.

7.36 Positron Emission Tomography (PET) radioactive tracer use

Use of PET tracers on campus are regulated by the NRC and the Radiation Safety Committee like any other radioisotopes used on campus with some additional requirements. Typically, these are transferred from the local cyclotron (Hospital) or purchased from an outside vendor who delivers them to OEHS. Both need prior approval from radiation safety office. An electronic transfer request must be submitted if the material is being walked over from the hospital. The **Transportation of Radioactive Material** form is an online request and is found on the OEHS website under Radiation Safety. A confirmation number is given over the phone or email.

If the material is being injected into an animal an ***in vivo radionuclide use-imaging plan of work form*** must be submitted. The form is an online submission and can be found on the OEHS website under the radiation safety tab. Transport of injected animals from housing to imaging or procedure rooms require lead shielding to reduce exposure to the public in hallways. It is recommended that a lead apron is draped over the cages during transport. Animal bedding is typically contaminated due to excretions and must be retained to decay. Cages must be held and monitored prior to release for cleaning. There is a form called ***Decay in Storage*** that must be complete for any bedding, cage, or deceased animal that has been subject to PET tracer work. All animal care takers must have basic radiation safety training, specific training and must wear a radiation monitoring badge.

Waste generated from PET tracers must be tagged with isotope, date, activity, and PI name. Radioactive waste from PET tracers can be disposed of as non-radioactive after decay to background as long as the decay in storage form is complete and the waste meets the criteria for disposal after performing the survey with the meter and recording the information on the form. All radioactive stickers or tags must be obliterated at disposal. The PI must get approval from radiation safety staff to use the decay in storage form.

See Appendix R for Transportation of Radioactive Material.
See Appendix S for the Decay in Storage form.

8.0 Ionizing Radiation Theory

Ionizing radiation has the ability to remove electrons from atoms, creating ions; hence, the term "ionizing radiation". The result of ionization is the production of negatively charged free electrons and positively charged ionized atoms. There are four types of ionizing radiation involved that can be classified into two groups: 1) photons, such as **gamma** and **x-ray**s, and 2) particles, such as **beta** particles (positrons or electrons), **alpha** particles (similar to helium nuclei, 2 protons and 2 neutrons), and **neutrons** (particles with zero charge, electrically neutral). Photons are electromagnetic radiation having energy, but no mass or charge, whereas particles typically have mass and charge as well as energy. Neutrons have mass and energy, but no charge, and are typically produced by man with machines, such as cyclotrons. All types of ionizing radiation can remove electrons from target atoms but interact with matter in different ways.
Particles are more highly ionizing; excitation and ionization are the primary interaction with matter, and potential for ionization increases as mass and charge increase. The range in tissue (depth to which the radiation may penetrate) for particles decreases as mass and charge increase. Photons, because they have no mass or charge, are less ionizing but more penetrating in matter.

Ionized atoms (free radicals), regardless of how they were formed, are much more active chemically than neutral atoms. These chemically active ions can form compounds that interfere with the process of cell division and metabolism. Also, reactive ions can cause a cascade of chemical changes in the tissue. The degree of damage suffered by an individual exposed to ionizing radiation is a function of several factors: type of radiation involved, chemical form of the radiation, intensity of the radiation flux (related to the amount of radiation and distance from the source), energy, and duration of exposure.

8.1 Radioactive Decay

Radioactive materials have an associated half-life, or decay time that is characteristic of the given radioisotope. As radiation is emitted, the material becomes more stable over time, decaying exponentially. Radioactive decay is a statistical measure. It is meaningless to measure how long one atom takes to decay, as the half-life is defined as the average amount of time required for half of a total amount of radioactive material to decay to a more stable state. Some radioisotopes have long half-lives; for example, ^{14}C takes 5,730 years for any given quantity to decay to half of the original amount of radioactivity. Other radioactive materials have short half-lives; ^{32}P has a two-week (14.3 day) half-life, and $^{99}Tc_m$ (used in human and animal nuclear medicine diagnostic procedures) has a half-life of 6 hours.

This is important for many reasons. When deposited in the human body, the half-life of the radioactive material present in the body affects the amount of the exposure. If the radioactive material contaminates a workbench or equipment, and is not removable, the amount of time before the contaminated items may be used again is determined by the radioactive half-life. Radioisotope decay using half-life minimizes costs and concerns in radioactive waste management.

The equation which is used to calculate radioactive decay is shown below.

$$\mathbf{A = A_0 e^{-\lambda t}}$$

Where
- A = Current amount of radioactivity
- A_0 = Original amount of radioactivity
- e = base natural log
- λ = the decay constant = $0.693/t_{1/2}$ (where $t_{1/2}$ = half-life)
- t = the amount of time elapsed from A_0 to A

It is important to be careful of the units used for the time. Days, hours and years must not be mixed in the calculation.

8.2 Units of Radiation Measurement

Two types of units are used for radiation, units of activity and units of exposure (dose). Units of activity quantify the amount of radioactive material present. Units of exposure quantify the amount of radiation absorbed or deposited in a specific material by a radiation source.

In the world today, two sets of units exist. They are the English units (Curie, Roentgen, Rad and Rem) and the SI or International Units (Becquerel, Gray and Sievert). In the United States, English units will typically be used in conjunction with SI units even though SI units are the professional standard. In our discussions the units used will always be English units. SI units are defined and described in the appendix on units.

Units of Activity

The unit of activity for radiation is the Curie, abbreviated Ci. Most laboratory facilities use only millicurie (mCi, 0.001 Ci) or microcurie (uCi, 0.000001 Ci) amounts of radioactive materials, since reliable data can best be obtained using low levels of activity for a given isotope. The Curie is an amount of radioactive material emitting 3.7×10^{10} disintegrations (particles or photons) per second (DPS). (The international, or SI, unit for radioactivity is the Becquerel, defined as one disintegration per second.) Activity can be determined with an appropriately calibrated radiation detection instrument. Common laboratory detection instruments are the liquid scintillation counter, Geiger-Mueller (GM) survey meter and low-energy gamma scintillation survey meter. These instruments detect a percentage of the total disintegrations and display in counts per minute (CPM).

It is important to note that the CPM readings from survey instruments are not the true amount of radiation present, since there are factors which decrease the detection capability of even the most sensitive instruments. Two factors influence radiation detection sensitivity: the geometry of the counting system and the energy of the radionuclide being measured. Lower energy radionuclides are detected with lower efficiencies than higher energy radionuclides. Detection instruments are calibrated with known sources with different energy levels to determine the efficiency of the instrument to account for these variables.

Therefore, to correct for the above sources of error in the measurements, a calculation must be made to standardize the units of activity used in all facilities licensed by the NRC.

It is required by NRC law that all records relevant to NRC licensed activities must be <u>maintained in units of DPM or microcuries</u>. To make the necessary conversion to the microcurie unit, the following formula must be used in all records of surveys, waste materials or radioactive solutions generated within the facility.

$$\text{CPM/Efficiency} = \text{DPM}$$
$$\text{DPM}/2.22 \times 10^{6} = \text{uCi}$$

<u>Units of Exposure</u>

The Roentgen, abbreviated as "R", is the unit for measuring the quantity of x-ray or gamma radiation by measuring the amount of ionization produced in air. One Roentgen is equal to the quantity of gamma or x-radiation that will produce ions carrying a charge of 2.58×10^{-4} coulombs per kilogram of air. An exposure to one Roentgen of radiation with total absorption will yield 87.7 ergs of energy deposition per gram of air at standard temperature and pressure. If human tissue absorbs one Roentgen of radiation, 96 ergs of energy will be deposited per gram of tissue. (The international units do not include the Roentgen, but simply use the amount of energy deposited in air as the descriptive term.)

The Roentgen is easy to measure with an ion chamber, an instrument that will measure the ions (of one sign) produced in air by the radiation. The ion chamber display reports Roentgen per hour or fractions thereof and may be calibrated to provide an approximation of tissue exposure. The OEHS and other departments with the potential for external radiation exposures use ion chambers for measuring exposure potential. It is a useful instrument for gamma and (with special detector window attachments) beta radiation; however, it is not quantitatively accurate for alpha or neutron radiation.

The rad and the rem are the two main radiation units used when assessing radiation exposure. The rad (radiation absorbed dose), is the unit of absorbed dose, and refers to the energy deposition by any type of radiation in any type of material. (The international unit for absorbed dose is the Gray; it is defined as being equal to 100 rads.) One rad equal 100 ergs of energy deposition per gram of absorber.

The rem (radiation equivalent man) is the unit of human exposure and is a dose equivalent (DE). (The international or SI unit for human exposure is the Sievert, which is equal to 100 rem.) It takes into account the biological effectiveness of different types of radiation. The target organ is important when assessing radiation exposures and a modifying factor is used in radiation protection to correct for the relative biological effectiveness (RBE or quality factor). Also, the chemical form of the radiation producing the dose is of critical importance in assessing internal doses, because different chemicals bind with different cell and/or organ receptor sites.

Additionally, some types of radiation cause more damage to biological tissue than other types. For example, one rad of alpha particles is twenty times more damaging than one rad of gamma rays. To account for these differences, a unit called a quality factor (QF) is used in conjunction with the radiation absorbed dose to determine the dose equivalent in rem:

rem dose = rad dose x QF

Tissue weighting factors, W_t, are used for incorporating the actual risk to tissues for different radioisotopes and tissues in dose calculations. These weighting factors assign multiplication factors for increasing or decreasing the actual biological risk to a given tissue.

Another way to evaluate risk to an individual for internal intakes of radioactive material is the use of body retention class, D, W or Y. These classes stand for Days, Weeks or Years of retention time in the human body and are specified in the Title 10 CFR 20 limits in the Appendix B.

This classification is based on the chemical form of the radioactive material, which affects the biochemical pathway and resultant target organ, therefore determining the retention time.

The dose rate is proportional to the radiation flux (number of particles or photons/square centimeter/second) and is expressed in rem/hour or mrem/hour. Radiation dosimeter readings are reported in mrem units. The dose rate can be estimated by using an ion chamber when the radiation source is a gamma or x-ray emitter. The ion chamber is useful in estimating dose for beta radiation if it equipped with a beta window, but special detectors for alpha or neutron radiation are required.

9.0 Laws and Regulations Concerning Radiation

The U.S. Nuclear Regulatory Commission is the branch of the federal government which regulates the licensing, use and disposal of radioactive materials. A multitude of laws set forth by the NRC must be obeyed. The State of Michigan also has laws, guidelines and regulations. In some cities, local regulations governing radioactive materials uses also exist, primarily with effluent discharges. Wayne State University possesses a radioactive materials license which contains further conditions of operation.

All the above laws, guidelines and regulations must be obeyed. If any of the regulating agencies or authorities determine that the laws or conditions are not complied with during the periodic inspections which they conduct, violations will be cited, and penalties may be imposed. Penalties may include civil penalties (which may be fines or criminal prosecution in court), sanctions, suspension, or termination of the license. For this reason, it is imperative that all principal investigators, workers and support staff involved in the receipt, use, or disposal of radioactive material is aware of and maintains compliance with these laws. The University discharge permit is on file at the Office of Environmental Health and Safety.

The Code of Federal Regulations, Title 10, Parts 19 and 20, are legal requirements set forth for all radioactive materials licensees. In particular, Part 20 contains the general practices, requirements and conditions by which all users of radioactive materials must abide. The majority of the regulations stated in 10 CFR 20 pertain to the way the programs and operations are managed and are the responsibility of the Health Physics staff.

9.1 Maximum Permissible Exposure

Exposure standards have been established by the NRC and set at a level where apparent injury due to ionizing radiation during a normal lifetime is unlikely. This limit is called the "maximum permissible exposure". However, personnel should not completely disregard exposures at or below these limits. It is the responsibility of each individual to keep his/her exposure to all radiation as low as is reasonable, and to avoid all exposures to radiation when such exposures are unnecessary.

The exposure limit for whole body exposures is lower than that for a single organ because all organs and tissues are exposed in a whole-body exposure, while only a single organ is involved in the single organ exposure limits. The risk to the organ is incorporated in the exposure calculations, which must be done if organs or tissues are exposed. Maximum permissible exposure limits to external radiation for adult and minor radiation workers are given in the following table (next page):

OCCUPATIONAL RADIATION EXPOSURE LIMITS

Part of Body	**Adult Yearly (mrem)**	**Minors yearly (< 18 yrs. Age) (mrem)**	**Adult ALARA Yearly (mrem)**
Whole Body, Head and Truck Active Blood Forming Organs **(TEDE)**	5,000	500	500
Lens of Eye **(LDE)**	15,000	1,500	1,500
Extremities **(SDE)** (Elbows, Forearms, Hands, Knees, Lower Legs, Feet)	50.000	5,000	5,000
Single Organ Dose **(TODE)**	50,000	5,000	5,000
Skin of Whole Body **(SDE)**	50,000	5,000	5,000

Notice that the following quantities are dose equivalents. The following definitions describe the given quantities. (Note: the types of doses are quantities; the units used for these quantities are the rem or the Sievert.)

DE: Dose Equivalent. The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and Sievert.

CDE: Committed Dose Equivalent. Means the dose equivalent to organs or tissues of reference that will be received from an intake of radioactive materials by an individual during the 50-year period following the intake.

EDE: Effective Dose Equivalent. It is the sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

CEDE: Committed Effective Dose Equivalent. It is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

DDE: Deep Dose Equivalent. Applies to external whole-body exposure. It is the dose equivalent at a tissue depth of 1 centimeter (1000 mg/cm^2).

TODE: Total Organ Dose Equivalent. The sum of the CDE and DDE for the maximally exposed organ.

SDE: Shallow Dose Equivalent. Applies to the external exposure of the skin or an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2), averaged over an area of 1 square centimeter.

LDE: Lens of Eye Dose Equivalent. Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at tissue depth of 0.3 centimeter (300 mg/cm^2).

TEDE: Total Effective Dose Equivalent. The sum of the deep dose equivalent (for external exposures) and the committed dose equivalent (for internal exposures).

9.2 Area Restrictions

All rooms or areas in which licensed quantities of radioactive materials are used or stored must be posted with a "Caution: Radioactive Material" sign, an "NRC Licensing and Regulation Information Bulletin" sign, and a "Notice To Workers" (NRC-3) sign. Door signs must include the principal investigator's name and phone number, and where he or she can be reached in the event of an emergency. Postings can be obtained from the OEHS.

The following chart definitions are set forth in the federal law for area restrictions.

DEFINITION OF AREA RESTRICTIONS
10 CFR 20.1003

Unrestricted Area
Any area to which access is neither controlled nor restricted by the licensee.

Restricted Area
An area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. A restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be used as a restricted area.

Controlled Area
Any area, outside of a restricted area but inside of the site boundary, to which access can be limited by the licensee for any reason.

Radiation Area
An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 mrem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

High Radiation Area

An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 100 mrem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Very High Radiation Area

An area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads* in 1 hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

*The exposure rates for Very High Radiation Areas are in rads, rather than rems, because potentially life-threatening exposures could result in areas with these fluxes of radiation.

At Wayne State University, most of the radiation use areas on campus are managed as restricted areas. Most radiation use areas are open to the public and may have both radiation workers and other individuals present often or all of the time. Members of the public are permitted to be present, as long they are escorted by a trained worker while in the restricted area or have been trained in radiation safety to work independently. Principal investigator training accomplishes training requirements for workers frequenting the laboratory but not handling radioactive materials.

Within the restricted area, it is imperative that strict surveillance be maintained to assure that significant exposure levels are not present, whether in the form of contamination, airborne levels of radiation or external exposure levels. For this reason, unrestricted area limits for contamination, exposures and/or releases are to be adhered to at all times, rather than restricted area limits.

We have been using the unrestricted area limits for several years at Wayne State University as a part of our ALARA program management.

Another very important requirement for restricted areas is the security of radioactive materials. It is the responsibility of all workers frequenting a restricted area to maintain security. This is discussed in the section on security of radioactive materials.

Other radiation area restriction categories (radiation area, high radiation area, etc.) exist only in a few specific locations, which are typically not accessible to the general public. In the event of emergency or other unusual situations, any of the restricted areas may be restricted to a more secure level to protect against radiation or any other hazard which may be present. If this were to occur, the area(s) would be clearly marked and posted with warning signs or barriers.

Warning signs and labels are available from the OEHS. The indiscriminate use of warning signs and/or labeling of non-radioactive materials with "Radioactive" stickers or labels is prohibited.

Safety Guidelines during radioisotope injections

Contaminated needles must not be bent, recapped, or removed from the syringe unless it can be demonstrated by the Principal Investigator that no alternative is feasible, and that a specific procedure requires such action. Under these circumstances, recapping or needle removal must be accomplished using a mechanical device (e.g., recapping stand, needle pliers).

Immediately after use, contaminated sharps must be placed in an appropriate sharps container. These containers must be:

- puncture resistant,
- appropriately labeled or color-coded,
- leak proof,
- and not handled in a manner that requires employees to reach by hand into the sharps container.

Principal Investigators, or designated laboratory supervisors, must reduce the risk of injuries by use of effective engineering controls. This includes safer medical devices designed to reduce the risk of injury from needlesticks and other sharp instruments. All sharps that have available products with engineered safety features must be identified, evaluated and, if appropriate, selected for use over devices that do not include such safety features.

Engineered safety sharps must be implemented if designed for the task being performed, commercially available, and effective. An engineered safety sharp is not appropriate if it jeopardizes worker safety by increasing the risk of injury (e.g., safety feature decreases line of sight when performing injections).

Evaluation Process:

- Evaluation of safer sharps devices must be done annually, following an injury event involving sharps, or a near miss incident, and be documented on the Sharps Safety Devices Evaluation Form. (See below.)
- Principal Investigators, or designated laboratory managers, must choose members from the non-managerial employees, who perform tasks with sharps exposure risk, to assist in the evaluation of safer sharps devices.
- Once the evaluation process is complete, if a new device has been chosen, its use must be implemented as soon as possible.
- If safer sharps devices are currently in use, the evaluation process must still be completed to determine if better options are now available.
- If a non-engineered sharp is selected over engineered options, a rationale for this decision must be documented. Cost is not an acceptable rationale for not using safety sharps.

Injury Report:

- Needle stick injuries must be attended to immediately. Seek medical attention by visiting the Henry Ford—Harbor town, Occupational Health clinic, or the Emergency Room.
- Safety Data Sheets of the hazards involved in the injury must be made available to the Radiation Safety Officer and the attending physician.

- Complete and submit a report of injury form to the Office of Enterprise Risk Management.
- Please submit the completed sharp devices evaluation form below with the RSC eprotocol.

SHARPS Safety Devices Evaluation Form	
Evaluation Performed Due To: ❑ Follow-up to an injury/exposure, or a near miss incident, involving a sharp ❑ Proactive review of sharps uses with radioactive materials.	
Evaluation Date:	Principal Investigator:
Department:	Building/Room Number:
Contact Employee:	Fax Number:
Phone Number:	E-mail:
Procedure involving a contaminated sharp:	
Type/Brand of sharp currently in use:	
Recommendation:	
❑ Elimination of sharp from procedure	❑ Substitution with a safe sharp device
❑ Use of engineering controls	❑ Implementation of safe work practices
❑ Personal Protective Equipment	❑ No recommendation, effective device(s) currently in use
Results of training and evaluation of new device:	
Type/Brand of sharp(s) evaluated:	
List employees involved in formal evaluation of safe sharps device(s):	
Training date for work with new safe sharps device(s):	
Device(s) formally in use following evaluation (selection/use date):	
Additional Comments:	

APPENDIX A

Application to use radioactive material must be completed online via WSU web-based e-protocol at http://research.wayne.edu/eprotocol/.

APPENDIX B

Radioisotopes Common at WSU

Isotope	Half-Life	Counting Method	Typical Efficiency*	Energy, MeV (b)	Energy, MeV (g)
^{3}H	12.35 years	L.S.C.	50%	0.0186	None
^{14}C	5730 years	L.S.C.	75%, 50%	0.511, 1.27	None
^{22}Na	2.6 years	Pancake	30%, 15%	0.546	0.511, 1.27
^{32}P	14.3 days	Pancake	50%	1.71	None
^{33}P	25.3 days	Pancake	15%	0.248	None
^{35}S	87.5 days	L.S.C., Pancake	75%, 5%	0.167	None
^{36}Cl	$3.0E^{5}$years	Pancake	30%	0.709	None
^{40}K	$1.28E^{9}$years	Pancake	50%	1.33	1.46
^{45}Ca	163 days	Pancake	15%	0.258	0.012(x-ray)
^{46}Sc	84 days	Pancake	20%, 15%	0.357	1.12, 0.889
^{51}Cr	27.7 days	Pancake	20%	None	0.320
^{55}Fe	2.7 years	Pancake	15%	0.232	None
^{63}Ni	100 years	L.S.C.	50%	0.0669	None
^{65}Zn	243.8 days	Pancake	15%, 15%	0.325	1.116
^{85}Sr	64.8 days	Pancake	15%	None	0.514
^{86}Rb	18.6 days	Pancake	50%, 20%	1.775	1.0771 (9% abundance)
^{111}In	2.8 days	Pancake	20%	None	0.245, 0.171
^{125}I	60 days	L.E.G.	50%	None	0.036
^{203}Hg	46.6 days	Pancake	25%, 10%	0.213	0.279

KEY
L.S.C.: Liquid Scintillation Counter
L.E.G.: Low Energy Gamma Scintillator
Pancake: Beta Pancake Detector

***These are not the efficiencies to use for your own laboratory surveys. Obtain the correct efficiencies for your survey meter from the most recent calibration report supplied by the OEHS. Liquid scintillation counters should have efficiencies as well. Run ^{3}H standards to obtain LSC efficiency; ask to borrow OEHS's standards if needed.**

Appendix C
Radionuclide Safety Data Sheets

<u>Commonly Used Isotopes</u>

C-14
Cr-51
H-3
I-125
P-32
P-33
S-35
Rb-86

<u>PET Tracers</u>

Zr-89
C-11
In-111
I-124
F-18
Cu-64
Lu-177

CARBON - 14
[14C]

PHYSICAL DATA

• Beta Energy: 156 keV (maximum)
49 keV (average) (100% abundance)
• Physical Half-Life: 5730 years
• Biological Half-Life: 12 days
• Effective Half-Life: 12 days (bound)
• Effective Half-Life: 40 days (unbound)
• Specific Activity: 4460 mCi/gram
• Maximum Beta Range in Air: 24.00 cm = 10 inches
• Maximum Beta Range in Water/Tissue: *0.28 mm = 0.012 inches
• Maximum Range in Plexiglas/Lucite/Plastic: 0.25 mm = 0.010 inches

*Fraction of ^{14}C beta particles transmitted through dead layer of skin: At 0.007 cm depth = 1%

RADIOLOGICAL DATA

• Critical Organ: Fat Tissue
• Routes of Intake: Ingestion, Inhalation, Skin Contact
• External exposure: Deep dose from weak ^{14}C beta particles is not a radiological concern
• Internal exposure & contamination: Primary radiological concerns

• Committed Dose Equivalent (CDE): 2.08 mrem/uCi (ingested)
(Fat Tissue) 2.07 mrem/uCi (puncture)
5.09 mrem/uCi (inhalation)

• Committed Effective Dose Equivalent (CEDE): 1.54 mrem/uCi (ingested)

• Annual Limit on Intake (ALI)*: 2 mCi (ingestion of labeled organic compound)
2000 mCi (inhalation of carbon monoxide)
200 mCi (inhalation of carbon dioxide)

*[1.0 ALI = 2 mCi (ingested C- 14 organic compound) = 5,000 mrem CEDE]

• Skin Contamination Dose Rate: 1090-1180 mrem per 1.0 uCi/cm 2 (7 mg/cm 2 depth)
• Dose Rate to Basal Cells from Skin Contamination, 1.0 uCi/cm 2 = 1400 mRad/hour.
• Immersion in ^{14}C Contaminated Air = 2.183E 7 mrem/year per uCi/cm 3 at 70 um depth of tissue and 4.07E 6
mrem/year per uCi/cm 3 value averaged over dermis.

SHIELDING

• None required (< or = 3 mm Plexiglas)

SURVEY INSTRUMENTATION

• Can detect ^{14}C using a G-M survey meter with a pancake probe; survey meter probe **must** be at close range (1 cm.)
• G-M survey meters have very low counting efficiency for ^{14}C (5%), therefore wipe tests should be performed.
• Liquid scintillation counter (indirect counting) may be used to detect removable ^{14}C on wipes.

RADIATION MONITORING DOSIMETERS

- Not needed (beta energy too low).
- ^{14}C Beta Dose Rate: 6.32 rad/hr at 1.0 cm. in air per 1.0 mCi ^{14}C
- Skin Contamination Dose Rate: 13.33 mRad/hr per uCi on skin
- Dose Rate from a 1 mCi isotropic point source of ^{14}C:

Distance	Rad/Hr
1.0 cm	1241.4
2.0 cm	250.4
15.2 cm	0.126
20.0 cm	0.0046

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Urinalysis: Not Required; however, prudent after a ^{14}C radioactive spill or suspected intake.

- Inherent volatility (at STP): Not Significant.

- Possibility of organic ^{14}C compounds being absorbed through gloves.

- Care should be taken NOT to generate $^{14}CO_2$ gas which could be inhaled.

- Internal Dose is the concern: Skin contamination, ingestion, inhalation, and puncture.

- Always wear a lab coat and disposable gloves when working with ^{14}C.

- The concentration of carbon in adipose tissue, including the yellow marrow, is about 3 times the average whole-body concentration. No other organ or tissue of the body concentrates stable carbon to any significant extent.

- The fractional absorption of dietary carbon (uptake to blood) is usually in excess of 0.90.

- Three main classes of carbon compounds may be inhaled: organic compounds, gases (CO or CO_2), and aerosols of carbon containing compounds such as carbonates and carbides.

Organic Compounds - most organic compounds are NOT very volatile under normal circumstances; the probability of these being inhaled as vapors is therefore small. In circumstances where such substances are
inhaled, it would be prudent to assume that once they enter the respiratory system they are instantaneously and completely translocated to the systemic circulation without changing their chemical form.

Gases - the inhalation of CO and its retention in body tissues has been studied extensively. Since gas has a
relatively low solubility in tissue water, doses due to absorbed gas in tissues are insignificant in comparison.
with doses due to the retention of CO bound to hemoglobin. CO_2 in the blood exists mainly as a bicarbonate.

Carbonates & Carbides - It is assumed that inhaled or ingested ^{14}C labeled compounds are instantaneously and uniformly distributed throughout all organs & tissues of the body where they are retained with a biological half-life of 12-40 days.

CHROMIUM - 51
[^{51}Cr]

PHYSICAL DATA

Gamma Energy: 320 keV (9.8% abundance) *
X-ray Energy: 5 keV (22% abundance) *
[*[Percent of disintegration resulting in this radiation being emitted]

No Betas Emitted

Specific Gamma Constant: 0.017 mR/hr per mCi at 1.0 meter

Physical Half-Life: 27.8 days
Biological Half Life: 616.0 days
Effective Half-Life: 26.6 days (whole body)

Specific Activity: 92,000 Curies/gram
Specific Activity (microspheres): 63.56 mCi/gram

RADIOLOGICAL DATA

- Critical Organ: Lower large intestine (LLI)
- Routes of Intake: Ingestion, inhalation, skin contact
- External & internal exposure and contamination are radiological concerns.

Committed Dose Equivalent (CDE): 0.15 mrem/uCi (ingested/gonad)
(gonad & lung) 1.41 mrem/uCi (inhalation/lung/Class W)

Committed Dose Equivalent (CDE): 1.20 mrem/uCi (ingested/GI tract/LLI)
0.22 mrem/uCi (inhaled/LLI Wall/Class D)

Committed Effective Dose Equivalent (CEDE): 0.107 mrem/uCi (ingested)
0.211 mrem/uCi (inhalation/Class D)
0.211 mrem/uCi (inhalation/Class W)

Annual Limit on Intake (ALI)*: 20 mCi (inhalation/Class W & Y)
52 mCi (inhalation/Class D/soluble)
40 mCi (ingestion)

*[1.0 ALI = 40 mCi (^{51}Cr ingested) = 5,000 mrem CEDE (Whole Body)]

SHIELDING

- Use 1/4" - 1/2" lead shielding for ^{51}Cr

Half - Value Layer (lead):	2.0 mm = 0.07"
Half - Value Layer (concrete):	2.8 cm = 1.10"
Half - Value Layer (Plexiglas):	4.8 cm = 1.90"
Tenth - Value Layer (lead):	5.6 mm = 0.22"
Tenth - Value Layer (concrete):	9.3 cm = 3.66"
Tenth - Value Layer (Plexiglas):	17.2 cm = 6.80"
Maximum range in lead:	7 mm. = 0.5"
Maximum range in Plexiglas:	65 cm. = 22.0"

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake/detector or standardized cylindrical probe may be used for the detection of ^{51}Cr.
- Smears or wipes counted in a liquid scintillation counter (indirect) may be used for the detection of **removable** ^{51}Cr surface contamination.

PERSONAL RADIATION MONITORING DOSIMETERS

Whole body & extremity badges required.

REGULATORY COMPLIANCE INFORMATION

- Derived Air Concentration (DAC): 2.0E -5 uCi/cc (Class D)
  (inhalation) 1.0E -5 uCi/cc (Class W)
  8.0E -6 uCi/cc (Class Y)

- Airborne Effluent Release Limit*: 6.0E -8 uCi/cc (Class D)
  3.0E -8 uCi/cc (Class W & Y)

* Applicable to the assessment & control of dose to the public (10 CFR 20.1302). If this concentration was inhaled continuously for over one year the resulting TEDE would be 50 mrem.

- Urinalysis: Not required; however, may be requested in the event of a spill of ^{51}Cr.

- Whole Body Bioassay: May be prudent in the event of a suspected intake of ^{51}Cr through ingestion, inhalation, skin absorption, or a wound.

- Gamma (photon) exposure rates from 1.0 mCi ^{51}Cr point source:

Distance	mRad/hr.
1.0 cm	160.0
5.0 cm	6.4
10.0 cm	1.6
100.0 cm	0.016

- Inherent Volatility (STP): Insignificant/Negligible

HYDROGEN - 3
[^3H]

PHYSICAL DATA

- Beta Energy: 18.6 keV (maximum)
  5.7 keV (average) (100% abundance)
- Physical Half-Life: 12.3 years
- Biological Half-Life: 10 - 12 days
- Effective Half-Life: 10 - 12 days *

Forcing liquids to tolerance (3-4 liters/day) will reduce the effective half-life of ^3H by a factor of 2 or 3. (Relatively easy to flush out of system with fluids.

- Specific Activity: 9640 Ci/gram
- Maximum Beta Range in Air: 6 mm = 0.6 cm = 1/4"
- Maximum Beta Range in Water: 0.006 mm = 0.0006 cm = 3/10,000"
- Penetrability in Matter or Tissue: Insignificant*

*[0% of beta particle energy transmitted through dead layer of skin]

RADIOLOGICAL DATA

- Least radiotoxic of all radionuclides
- Critical Organ: Body Water or Tissue
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
- External exposure from weak ^3H beta energy - not a radiological concern
- Internal exposure & contamination are primary radiological concerns

- Committed Dose Equivalent (CDE): 64 mrem/mCi (ingested)
  64 mrem/mCi (inhaled)
  64 mrem/mCi (puncture)

- Committed Effective Dose Equivalent (CEDE): 90 mrem/mCi (ingested)
  63 mrem/mCi (inhaled)

- Annual Limit on Intake (ALI)*: 80 mCi (ingestion or inhalation) [^3H_2O]
  - [1.0 ALI = 80 mCi (3 H) = 5,000 mrem CEDE]

- Skin Contamination Exposure Rate: 57,900 mRad/hr/mCi (contact)*
  * Exposure rate to dead layer of skin only
  * Skin contamination of 1.0 uCi/cm 2 = 0 mRad/hr dose rate to basal cells

- Rule of Thumb: 0.001 uCi/ml of ^3H in urine sample is indicative of a total integrated whole-body dose of approximately 10 mrem (average person) if no treatment is instituted (i.e., flush with fluids) [NCRP-65, 1980]

SHIELDING

- None required

SURVEY INSTRUMENTATION

- **CANNOT** detect ^3H using a G-M or NaI survey meter
- Liquid scintillation counter (indirect) is the only monitoring method

RADIATION MONITORING DOSIMETERS

- Whole Body Badge or Finger Rings: Not needed (beta energy too low)

RADIOACTIVE WASTE
• Solid, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC) : 2.0 E -5 uCi/cc (occupational)

• Airborne Effluent Release Limit: 1.0 E -7 uCi/cc *
***** [Applicable to the assessment & control of dose to the public (10 CFR 20.1302). If this concentration was inhaled continuously for over one year the resulting TEDE would be 50 mrem.]

• Controlled Area Removable Contamination Limit: 2,200 dpm/100 cm^2

• Urinalysis (Byproduct License): **Required** when handling □□100 mCi ^{3}H

GENERAL RADIOLOGICAL SAFETY INFORMATION

• Inherent Volatility (at STP): **SUBSTANTIAL**

• Experimental uses include total body water measurements & in-vivo labeling of proliferatory cells by injection of tritium-labeled compounds (i.e., thymidine). Tritium labeling is also used in a variety of metabolic studies.

• Oxidation of ^{3}H gas in air is usually slow (< 1% per day).

• Absorption of ^{3}H inhaled in air is much less when it is present as elemental ^{3}H than as tritiated water (HTO).

• Tritium penetrates the skin, lungs, and GI tract either as tritiated water or in the gaseous form.

• As gaseous hydrogen, ^{3}H entering the lung or GI tract is completely absorbed and rapidly dispersed within the body.

• Some ^{3}H is incorporated into cellular components and has a long turnover rate.

• Forcing fluids reduces integrated internal exposures from ^{3}H.

• Monitor for ^{3}H contamination using only wipe-testing (bench tops, floors, refrigerator/freezer handles, phone, etc.).

• Always wear a lab coat & disposable gloves when handling ^{3}H.

• Skin contamination, inhalation, ingestion, or absorption through the skin is assumed to be completely and instantaneously absorbed and rapidly mixed with total body water.

• The volume of total body water (standard man) is 42,000 ml.

• The concentration of ^{3}H in urine is assumed to be the same as in total body water.

• Detection limit of ^{3}H in urine: 1.08E -5 uCi/ml (approximately)

• For a continuous inhalation exposure at a rate of 1/365 of an ALI per day, the equilibrium concentration of ^{3}H in urine is 0.073 uCi/ml. [NOTE: 1/365 of 80 mCi (ALI) = 219 uCi]

• The predicted concentration activity normalized to unit intake from inhalation is 2.204 E -5 uCi/ml/uCi of ^{3}H

• Beta dose rates from 1.0 mCi ^{3}H point source:

Distance	Rad/hr
0.25 cm	10,293.00
0.50 cm	28.12

IODINE - 125
[^{125}I]

PHYSICAL DATA

• Gamma Energies: 35.5 keV (7% abundance/93% internally converted, gamma)
(No betas emitted) 27.0 keV (113%, x-ray)
27-32 keV (14%, x-ray)
31.0 keV (26%, x-ray)

• Specific Gamma Ray Constant: 0.27 to 0.70 mR/hr per mCi at 1 meter
(Current literature indicates 0.27 mR/hr per mCi at 1 meter)

• Physical Half-Life: 60.1 days
• Biological Half-Life: 120-138 days (unbound iodine) - thyroid elimination
• Effective Half-Life: 42 days (unbound iodine) - thyroid gland

• Specific Activity: 17,400 Ci/gm (theoretical/carrier free)
• Intrinsic Specific Activity: 22.0 Ci/millimole

RADIOLOGICAL DATA

• Critical Organ (Biological Destination): Thyroid
• Routes of Intake: Ingestion, inhalation (most probable), puncture, wound, skin contamination (absorption)
• External and internal exposure and contamination concerns exist in use of ^{125}I

• Committed Dose Equivalent (CDE):
(Organ Doses) 814 mrem/mCi (thyroid/inhalation/class "D")
1185 mrem/mCi (thyroid/ingestion/NaI form)
910 mrem/mCi (thyroid/inhalation)
1258 mrem/mCi (any organ/puncture/adult)

• Committed Effective Dose Equivalent(CEDE): 24 mrem/mCi (whole body/inhalation)

• Annual Limit on Intake (ALI):
40 uCi ^{125}I (all compounds) (ingestion / CDE / 50 rem to Thyroid)
100 uCi ^{125}I (all compounds) (ingestion / CEDE / 5 rem to Whole Body)
60 uCi ^{125}I (all compounds) (inhalation / CDE / 50 rem to Thyroid)
200 uCi ^{125}I (all compounds) (inhalation / CEDE / 5 rem to Whole Body)

[1.0 ALI = 40 uCi ^{125}I (ingested) = 50,000 millirem CDE to Thyroid]
[1.0 ALI = 60 uCi ^{125}I (inhaled) = 50,000 millirem CDE to Thyroid]
[1.0 ALI = 200 uCi ^{125}I (inhaled) = 5,000 millirem CEDE to Whole Body]
[HP / April 1990 / Vol. 58 / No. 4 and Varskin (et al) calculations]

SHIELDING
• Lead foil or sheets (1/32 to 1/16 inch thick): 0.152 mm lead foil
• Half Value Layer: 0.02 mm = 0.008 inches

SURVEY INSTRUMENTATION

• Survey meter equipped with a low energy NaI scintillation probe is necessary.
• Survey meters equipped with GM pancakes or end window GM probes are inefficient for low-energy gamma emitters. These probes are not useful for ^{125}I contamination monitoring.

DOSE RATES(from unshielded 1.0 mCi isotropic point source)

Distance	mRads/hr.
1.00 cm	156 - 275
10.00 cm	15.5 - 27.5
100.00 cm	0.156 -0.28
6.00 in	6.5

(Some literature indicates 0.7 mRad/hr per mCi at 100 cm.)
• Individuals who will be using ^{125}I in the NaI or KI chemical form are required to obtain a thyroid scan to be used as a baseline reference prior to use.

• The thyroid gland accumulates 20 - 30% of the soluble radioiodine taken in by the body. All radioiodines in the body can be assumed to be eliminated quite rapidly via the urine.

• Thyroid Bioassay is **required by law** when handling > 1 mCi in the ^{125}I in the sodium or potassium iodide chemical form. In accordance with the NRC license and WSU's commitment to ALARA, the threshold amount is taken to be 0.1 mCi. The thyroid scan is to be obtained not less than 6 hours but no more than 72 hours after the handling or use of that quantity and form of ^{125}I. In addition, all workers who assist or observe in manipulations of the above quantity and type of ^{125}I or are sufficiently close to the process so that intake is possible (within a few meters and in the same room) are required to obtain thyroid scans under the same conditions listed above.

• Fume hood sash glass provides adequate shielding for most iodination. If extra shielding is required, be sure it is configured so it does not impede air flow into the hood.

• Shielding is not required for most uses of this nuclide due to the low energy and low amounts typically used. Larger activities may be shielded with leaded acrylic or thin lead sheets.

• Use a cannula adapter needle to vent stock vials of ^{125}I used for iodination. This prevents puff releases.

• Segregate waste from iodination (free) from other (bound) ^{125}I waste and store it in the fume hood, in tightly sealed ziplock bags (solid waste) or screw top containers (liquid waste) until waste pickup.

• Cover test tubes used to count or separate fractions from iodination with parafilm or other tight caps to prevent release while counting or moving outside the fume hood.

PHOSPHORUS – 32
[^{32}P]

PHYSICAL DATA

- Beta energy: 1.709 MeV (maximum)
  0.690 MeV (average, 100% abundance)
- Physical half-life: 14.3 days
- Biological half-life: 1155 days
- Effective half-life: 14.1 days (bone) / 13.5 days (whole body)

- Specific activity: 285,000 Ci/gm
- Maximum range in air: 610 cm = 240 inches = 20 feet
- Maximum range in water/tissue: 0.76 cm = 1/3 inch
- Maximum range in Plexiglas/Lucite/plastic: 0.61 cm = 3/8 inch
- Half-Value Layer (HVL): 2.00 mm (water/tissue)

RADIOLOGICAL DATA

- Critical organ (biological destination) (soluble forms): Bone
- Critical organs (insoluble forms or non-transportable ^{32}P compounds): Lung (inhalation) and G.I. tract/lower large intestine (ingestion)
- Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- External and internal exposure from ^{32}P

- Committed Dose Equivalent (CDE):
(Organ Doses) 32 mrem/uCi (ingested)
  37 mrem/uCi (puncture)
  96 mrem/uCi (inhaled/Class W/lungs)
  22 mrem/uCi (inhaled/Class D/bone marrow)

- Committed Effective Dose Equivalent (CEDE): 7.50 mrem/uCi (ingested/WB)
  5.55 mrem/uCi (inhale/Class D)
  13.22 mrem/uCi (inhale/Class W)

- Annual Limit on Intake (ALI)*: 600 uCi (ingested/All Compounds)
  900 uCi (inhalation/except phosphates)
  400 uCi (inhalation/phosphates)

*[1.0 ALI = 600 uCi ^{32}P ingested (all compounds) = 5,000 mrem CEDE (Whole Body)]

- Skin contamination dose rate: 8700-9170 mrem/uCi/cm ^{2} /hr. (7 mg/cm ^{2} or 0.007 cm depth in tissue).
- Dose rate to basal cells from skin contamination of 1.0 uCi/cm ^{2} (localized dose) = 9200 mRad/hr.
- Bone receives approximately 20% of the dose ingested or inhaled for soluble ^{32}P compounds.
- Tissues with rapid cellular turnover rates show higher retention due to concentration of phosphorous in the nucleoproteins.
- ^{32}P is eliminated from the body primarily via urine.
- Phosphorus metabolism; see ^{33}P Fact Sheet.

SHIELDING

- < less than or equal to 3/8 inch thick Plexiglas/acrylic/Lucite/plastic/wood.
- Do not use lead foil or sheets! Penetrating Bremsstrahlung x-ray will be produced!

• Use lead sheets or foil to shield Bremsstrahlung x-rays only **after** low density Plexiglas/acrylic/Lucite/wood shielding.

SURVEY INSTRUMENTATION
• GM survey meter and a pancake probe.
• Low-energy NaI probe is used **only to detect Bremsstrahlung x-rays.**
• Liquid scintillation counter (indirect counting) may be used to detect removable surface contamination of ^{32}P on smears or wipes.

DOSE RATES
(from unshielded 1.0 mCi isotropic point source)

Distance	Rads/hr
1.00 cm	348
15.24 cm	1.49
10.00 ft	0.0015

• 78,000 mRad/hr at surface of 1.0 mCi ^{32}P in 1 ml liquid.
• 26,000 mRad/hr at mouth of open vial containing 1.0 mCi ^{32}P in 1.0 ml liquid.

GENERAL PRECAUTIONS
• Because it is a bone seeker, special precautions must be taken to minimize any chance of introducing into the body.

• Airborne contamination can be generated through drying (dust), rapid boiling, or expelling solutions through syringe needles and pipette tips, due to aerosols.

• Personnel radiation monitors (whole body and finger rings) are **required** when handling > 1.0 mCi of ^{32}P at any time.

• Never work directly over an open container; avoid direct eye exposure from penetrating ^{32}P beta particles.

• Always wear a lab coat and disposable gloves when handling ^{32}P.

• Monitor personnel work areas and floors using a GM survey meter equipped with a pancake (beta) probe for surface contamination.

• Monitor for removable surface contamination by smearing or wiping where ^{32}P is used.

• Use low-density (low atomic number) shielding material to shield ^{32}P and reduce the generation of Bremsstrahlung x-rays. The following materials are low atomic number materials: Plexiglas, acrylic, Lucite, plastic, wood, or water.

• Do NOT use lead foil, lead sheets, or other high density materials (metals) to shield ^{32}P directly. Materials with atomic number higher than that of aluminum (Z = 13) should NOT be used. Penetrating Bremsstrahlung x-rays will be generated in lead and other high density shielding material.

• Safety glasses or goggles are recommended when working with ^{32}P.

• Typical GM survey meter with pancake probe efficiency is about 45%. The typical liquid scintillation counter counting efficiency for ^{32}P (full window/maximum) is > 85%.

• Typical detection limit of ^{32}P in urine specimens using a liquid scintillation counter = 1.1 E -7 uCi/ml.

PHOSPHORUS - 33
[^{33}P]

PHYSICAL DATA

- Beta energy: 0.249 MeV (maximum, 100% abundance)
  0.085 MeV (average)

- Physical half-life: 25.4 days
- Biological half-life: 19 days (40% of intake; 30% rapidly eliminated from body, remaining 30% decays)
- Effective half-life: 24.9 days (bone)
- Specific activity: 1,000 - 3,000 Ci/millimole

- Maximum beta range in air: 89 cm = 35 inches = 3 feet
- Maximum range in water/tissue: 0.11 cm = 0.04 inch
- Maximum range in Plexiglas/Lucite/plastic: 0.089 cm = 0.035 inch
- Half-Value Layer (HVL): 0.30 mm (water/tissue)

RADIOLOGICAL DATA

- Critical organ (biological destination) (soluble forms): Bone marrow
- Critical organs (insoluble forms or non-transportable ^{33}P compounds): Lung (inhalation) and G.I. tract/Lower large intestine (ingestion)
- Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- Internal exposure and contamination are the primary radiological concerns
- Committed Dose Equivalent (CDE): 0.5 mrem/mCi (inhalation)
- Skin contamination dose rate: 2,910 mrem/hr/uCi/cm 2 (7 mg/cm 2 or 0.007 cm depth in tissue)
- Fraction of ^{33}P beta particles transmitted through the dead skin layer is about 14%.
- Tissues with rapid cellular turnover rates show higher retention due to concentration of phosphorus in the nucleoproteins.
- ^{33}P is eliminated from the body primarily via urine.
- Phosphorus metabolism: 30% is rapidly eliminated from body
  40% has a 19-day biological half-life.
  60% of ^{33}P (ingested) is excreted from body in first 24 hrs.

SHIELDING

- Not required; however low density material is recommended, e.g., 3/8 inch thick Plexiglas, acrylic, Lucite, plastic or plywood.

SURVEY INSTRUMENTATION

- GM survey meter with a pancake probe.
- Liquid scintillation counting of wipes may be used to detect removable surface contamination.

PERSONNEL DOSIMETERS

- Are not required since they do not detect this low energy nuclide.

GENERAL PRECAUTIONS

- Inherent volatility (STP): Insignificant
- Skin dose and contamination are the primary concerns.
- Drying can form airborne ^{33}P contamination.
- Monitor work areas for contamination, using smears or wipes to check for removable contamination.

SULFUR - 35
[^{35}S]

PHYSICAL DATA

- Beta energy: 167 keV (maximum)
  53 keV (average) (100% abundance)
- Physical Half Life: 87.4 days
- Biological Half Life: 623 days (unbound ^{35}S)
- Effective Half Life: 44 - 76 days (unbound ^{35}S)
- Specific Activity: 42,400 Ci/g

- Maximum Beta Range in Air: 26.00 cm. = 10.2 in.
- Maximum Beta Range in Water or Tissue: 0.32 mm. = 0.015 in.
- Maximum Beta Range in Plexiglas or Lucite: 0.25 mm. = 0. 01 in.

- Fraction of ^{35}S betas transmitted through dead layer of skin = 12%

RADIOLOGICAL DATA

- Critical organ: Testis
- Routes of Intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- External exposure (deep dose) from weak ^{35}S beta particles is not a radiological concern.
- Internal exposure and contamination are the primary radiological concerns.

- Committed dose equivalent (CDE): 10.00 mrem/uCi (ingested)
  0.352 mrem/uCi (puncture)

- Committed Effective Dose Equivalent (CEDE): 2.6 mrem/uCi (ingested)*
  *(Assumes a 90-day biological half life)
- Annual Limit on Intake (ALI)*: 10 mCi (ingestion of inorganic ^{35}S compounds)
  6 mCi (Ingestion of elemental ^{35}S)
  8 mCi (ingestion of sulfides or sulfates/LLI)**
  10 mCi (inhalation of ^{35}S vapors)
  20 mCi (inhalation of sulfides or sulfates)
  2 mCi (inhalation of elemental ^{35}S)

*1.0 ALI = 10 mCi (inhaled ^{35}S vapors) = 5,000 mrem CEDE
** 1.0 ALI = 8 mCi (ingestion sulfides/sulfates LLI) = 50,000 mrem CDE

- Skin Contamination Dose Rate: 1,170 - 1, 260 mrem/uCi/cm ^{2} /hr. (7.0 mg/cm ^{2} depth)
- Beta Dose Rates for ^{35}S: 14.94 rad/h (contact) in air per 1.0 mCi
  0.20 rad/h (6 inches) in air per 1.0 mCi

SHIELDING

- None required (less than or equal to 3 mm Plexiglas shields; shielding optional).

SURVEY INSTRUMENTATION

- can detect using a thin window G-M survey meter (pancake), however, probe **MUST** be at close range, recommend 1 cm distance.
- G-M survey meter has low efficiency, usually 4 - 6%.

• Liquid scintillation counter (wipes, smears) may be used for secondary, **but will NOT detect non-removable contamination!**

RADIATION MONITORING DEVICES

• (Badges): Not needed, because ^{35}S beta energy is too low, and is not an external radiation hazard

• Dose Rate from a 1 millicurie unshielded isotropic point source of ^{35}S:

Distance	Rad/hr
1.0 cm	1173.6
2.5 cm	93.7
15.24 cm	0.2
20.00 cm	0.01

GENERAL RADIATION SAFETY INFORMATION

• Urinalysis: Not required but may be requested by Health Physics staff after a spill or personnel contamination involving ^{35}S.
• Inherent volatility (STP): **SIGNIFICANT** for ^{35}S methionine and cysteine.
• Radiolysis of ^{35}S amino acids (cysteine and methionine) during storage and use may lead to the release of volatile impurities. Volatile impurities are small □□□0.05%).
• Metabolic behavior of organic compounds of sulfur (cysteine and methionine) differs considerably from the metabolic behavior of inorganic compounds.
• Organic compounds of sulfur (cysteine and methionine) become incorporated into various metabolites. Thus, sulfur entering the body as an organic compound is often tenaciously retained.
• The fractional absorption of sulfur from the gastrointestinal tract is typically > 60% for organic compounds of sulfur. Elemental sulfur is less well absorbed from the GI tract than are inorganic compounds of the element (80% for all inorganic compounds and 10% for sulfur in its elemental form). Elemental sulfur is an NRC inhalation Class W (meaning it is retained for weeks in the body).
• Inhalation of the gases SO_2, COS, H_2S, and CS_2 must be considered. Sulfur entering the lungs in these forms is completely and instantaneously translocated to the transfer compartment; from there, its metabolism is the same as that of sulfur entering the transfer compartment following ingestion or inhalation of any other organic compound of sulfur.
• Contamination of internal surfaces of storage and reaction vessels may occur (rubber stoppers, gaskets or o rings).
• Vials of ^{35}S labeled cysteine and methionine should be opened and used in ventilated enclosures (exhaust hoods).
• The volatile components of ^{35}S labeled amino acids should be opened and used in ventilated enclosures (exhaust hoods).
• The volatile components of ^{35}S labeled cysteine and methionine are presumed to be hydrogen sulfide (H_2S) and methyl mercaptan (CH_3SH), respectively.
• ^{35}S vapors may be released when opening vials containing labeled amino acids, during any incubating of culture or cells containing ^{35}S, and the storage of ^{35}S contaminated wastes.
• Excessive contamination can be found on the inside surfaces and in water reservoirs of incubators used for ^{35}S work. Most notable surface contamination can be found on rubber seals of incubators and centrifuges.
• Radiolytic breakdown may occur during freezing processes, releasing as much as 1.0 uCi of ^{35}S per 8.0 mCi vial of ^{35}S amino acid during the thawing process.
• ^{35}S labeled amino acids work should be conducted in an exhaust hood designated for radiolytic work.
• Vent ^{35}S amino acid stock vials with an open-ended charcoal-filled disposable syringe. Activated charcoal has a high affinity for ^{35}S vapors.

- Place an activated carbon or charcoal canister, absorbent sheet, or tray (50-100 grams of granules evenly distributed in a tray or dish) into an incubator to passively absorb ^{35}S vapors. Discard absorbers which exhibit survey meter readings above normal area background levels in the solid radioactive waste.

Rubidium-86
[^{86}Rb]

I. PHYSICAL DATA

Radiation Betas: 698 keV (9%); 1774 keV (91%)
Gamma & X-ray: 1077 keV (9 %)
Gamma Constant b: 0.054 mrem/hr per mCi @ 1.0 meter [1.458E-5 mSv/hr per MBq @ 1.0 meter]
Half-Life [T½]: Physical T½: b 18.7 days
Biological T½: GI: <1day; Total Body: ~ 45 days
Effective T½: GI: ~1 day; Total Body: ~ 13 days
Specific Activity: 8.14 E4 Ci/g [3.01 E15 Bq/g] max.

II. RADIOLOGICAL DATA

Radiotoxicity: 6.86E-9 Sv/Bq (25 mrem/uCi) of 86Rb ingested [bone]; 2.53E-9 effective
3.3E-9 Sv/Bq (12 mrem/uCi) of 86Rb inhaled [lung]; 4.3E-9 Sv/Bq [bone]
Critical Organ: Bone (ingestion); Bone surface, Lung (inhaled)
Intake Routes: Ingestion, inhalation, puncture, wound, skin contamination (absorption);
Radiological Hazard: External & Internal Exposure; Contamination

III. SHIELDING

Photons:
Lead [Pb]

Half Value Layer [HVL]	Tenth Value Layer [TVL]
14 mm (0.02 inches)	41 mm (0.08 inches)

Betas: 0.66 cm Plexiglas (total absorption)
- The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling 86Rb.

V. DETECTION & MEASUREMENT

Portable Survey Meters:
Geiger-Mueller [e.g. Bicron PGM] to assess shielding effectiveness
Wipe Test: Liquid Scintillation Counter

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake].
- Store 86Rb (including waste) behind lead shielding [½+ inch thick]; lead bricks may be necessary. Survey (with GM meter) to check adequacy of shielding (accessible dose rate < 2 mR/hr; should be background).
- Use shielding to minimize exposure while handling ^{86}Rb.
- Use tools to handle ^{86}Rb sources and contaminated objects; avoid direct hand contact. Near ^{86}Rb sources, the beta dose rate can be much higher than the gamma dose rate.
- Rubidium is an alkali earth metal; elemental form reacts (chemically) violently with water.

VII. GENERAL PRECAUTIONS

1. Maintain your occupational exposure to radiation As Low As Reasonably Achievable [ALARA].
2. Ensure all persons handling radioactive material are trained, registered, & listed on an approved protocol.
3. Review the nuclide characteristics on (reverse side) prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the responsible Principal Investigator to view the protocol information.
4. Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce internal and external radiation dose by monitoring the worker and the work area after each use of radioactive material, then promptly cleaning up any contamination discovered. Use the smallest amount of radioisotope possible so as to minimize radiation dose and radioactive waste.
5. Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal. Perform and record regular lab surveys.
6. Provide for safe disposal of radioactive waste by following institutional Waste Handling & Disposal Procedures. Avoid generating mixed waste (combinations of radioactive, biological, and chemical waste). Note that lab staff may not pour measurable quantities of radioactive material down the drain.
7. If there is a question regarding any aspect of the radiation safety program or radioactive material use, contact Radiation Safety.

VIII. LAB PRACTICES

1. Disposable gloves, lab coats, and safety glasses are the minimum PPE [Personal Protective Equipment] required when handling radioactive material. Remove & discard potentially contaminated PPE prior to leaving the area where radioactive material is used.
2. Clearly outline radioactive material use areas with tape bearing the legend "radioactive". Cover lab bench tops where radioactive material will be handled with plastic-backed absorbent paper. change this covering periodically and whenever it's contaminated. Alternatively cover benches with thick plastic sheeting (i.e., painter's drop cloth), periodically wipe it clean and replace it if torn.
3. Label each unattended radioactive material container with the radioactive symbol, isotope, activity, and, except for waste, the ICN [inventory control number]. Place containers too small for such labels in larger labeled containers.
4. Handle radioactive solutions in trays large enough to contain the material in the event of a spill.
5. Never eat, drink, smoke, handle contact lenses, apply cosmetics, or take/apply medicine in the lab; keep food, drinks, cosmetics, etc. out of the lab entirely. Do not pipette by mouth.
6. Never store [human] food and beverage in refrigerators/freezers used for storing radioisotopes.
7. Prevent skin contact with skin-absorbable solvents containing radioactive material.
8. Fume hoods and biological safety cabinets for use with non-airborne radioactive material must be approved (through the protocol) and must be labeled "Caution Radioactive Material".
9. All volatile, gaseous, or aerosolized radioactive material must be used only in a properly operating charcoal and/or HEPA filtered fume hood or Biological Safety Cabinet bearing a Caution Airborne Radioactivity hood label, unless otherwise specified in writing by the Radiation Safety Officer. In particular, radioactive iodination must be performed only in these specially designed fume hoods. The Radiation Safety Officer (through a protocol) must approve all such use.
10. Take special precautions when working with radioactive compounds that tend to become volatile [e.g. 35S labeled amino acids, 125I - iodine tends to volatilize in acidic solutions]. These precautions may include using the materials only within an approved fume hood, protecting the house vacuum system with primary and secondary vapor trapping devices, and covering active cell cultures with carbon-impregnating paper.
11. Use sealed containers and appropriate secondary containment to carry radioactive material between rooms. Notify Radiation Safety staff before taking any radioactive material off site.

Zirconium-89
[^{89}Zr]

I.PHYSICAL DATA

Radiation: Gamma: 511 keV (23% by positron emission & 77% by electron capture)
Emax of 897 keV and Eave of 396.9 keV (for positrons)
Specific Gamma Dose Constant: 0.98494 rem / hour per Ci at 1 meter
Half-life (T1/2): 3.3 days
Specific Activity: No carrier added

II.RADIOLOGICAL DATA

Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination/absorption Radiological Hazard; External & Internal Exposure; Contamination
Annual Limit of Intake (ALI) for Inhalation:100 MBq Ingestion (ALI): 60 MBq

III. SHIELDING

Gamma: Half Value Layer (HVL) Tenth Value Layer (TVL) Lead (Pb) 6 mm 17 mm
The accessible dose rate should be background (0.05 mR/hour) and should be less than 2 mR/ hour.

IV. DETECTION AND MEASUREMENT

Geiger Muller Counter to access shielding effectiveness.
Well Counter, Low energy gamma detector (Ludlum 44-21) for contamination surveys Wipe test: Gamma Counter.

V.DOSIMETER MONITORING

Always wear radiation monitoring badges (body & ring) while working with Zr-89.

VI. GENERAL PRECAUTIONS

1. Maintain your occupational exposure to radiation As Low As Reasonably Achievable [ALARA].
2. Ensure all persons handling radioactive material are trained, registered, & listed on an approved protocol.
3. Review the nuclide characteristics on prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the responsible Principal Investigator to view the protocol information.
4. Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce internal and external radiation dose by monitoring the worker and the work area after each use of radioactive material, then promptly cleaning up any contamination discovered. Use the smallest amount of radioisotope possible so as to minimize radiation dose and radioactive waste.
5. Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal. Perform and record regular lab surveys.
6. Provide for safe disposal of radioactive waste by following institutional Waste Handling & Disposal Procedures. Avoid generating mixed waste (combinations of radioactive, biological, and chemical waste). Note that lab staff may not pour measurable quantities of radioactive material down the drain.
7. If there is a question regarding any aspect of the radiation safety program or radioactive material use, contact Radiation Safety.

VII. LABORATORY PRACTICES

1.Disposable gloves, lab coats, and safety glasses are the minimum PPE [Personal Protective Equipment] required when handling radioactive material. Remove & discard potentially contaminated PPE prior to leaving the area where radioactive material is used.

2.Clearly outline radioactive material use areas with tape bearing the legend "radioactive". Cover lab bench tops where radioactive material will be handled with plastic-backed absorbent paper; change this covering periodically and whenever it's contaminated. Alternatively cover benches with thick plastic sheeting (i.e., painter's drop cloth), periodically wipe it clean and replace it if torn.

3.Label each radioactive material container with the radioactive symbol, isotope, activity, and, including the waste. Survey and document before disposal of waste after decay to background.

4.Handle radioactive solutions in trays large enough to contain the material in the event of a spill.

5.Never eat, drink, smoke, handle contact lenses, apply cosmetics, or take/apply medicine in the lab; keep food, drinks, cosmetics, etc. out of the lab entirely. Do not pipette by mouth.

6.Never store [human] food and beverage in refrigerators/freezers used for storing radioisotopes.

7.Prevent skin contact with skin-absorbable solvents containing radioactive material.

8.Fume hoods and biological safety cabinets for use with non-airborne radioactive material must be approved (through the protocol) and must be labeled "Caution Radioactive Material".

9.All volatile, gaseous, or aerosolized radioactive material must be used only in a properly operating charcoal and/or HEPA filtered fume hood or Biological Safety Cabinet bearing a Caution Airborne Radioactivity hood label, unless otherwise specified in writing by the Radiation Safety Officer. The Radiation Safety Officer (through a protocol) must approve all such use.

10.Take special precautions when working with radioactive compounds that tend to become volatile These precautions may include: using the materials only within an approved fume hood, protecting the house vacuum system with primary and secondary vapor trapping devices, and covering active cell cultures with carbon-impregnating paper.

11.Use sealed containers and appropriate secondary containment to carry radioactive material

^{111}In
Indium-111

PHYSICAL DATA

Primary Radiation: Gamma – 245 keV (94% abundance), 171 keV (90% abundance), 23 keV (69% abundance)
Gamma Constant: 3.7 mrem/hr at 30 cm from 1 mCi [9.9E-4 mSv/hr at 30 cm from 1 MBq]
Physical Half-Life [$T_{½}$]: 2.80 days

Specific Activity: 4.19E5 Ci/g [1.55E16 Bq/g]

RADIOLOGICAL DATA

Radiotoxicity: 1,330 mrem/mCi [3.59E-7 mSv/Bq] of ^{111}In ingested [CEDE] 840 mrem/mCi [2.27E-7 mSv/Bq] of ^{111}In inhaled [CEDE]
Critical Organ: Lower Large Intestine

Intake Routes: Ingestion, inhalation, puncture, wound, skin contamination (absorption);
Radiological Hazard: Internal and External Exposure, Contamination

SHIELDING

Lead [Pb]

Half Value Layer [HVL]	Tenth Value Layer [TVL]
<1 mm	3 mm

The accessible dose rate should be background and must be < 2 mR/hr.

DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{111}In

DETECTION & MEASUREMENT

Portable Survey Meters:

Geiger-Mueller [e.g. Bicron PGM,] to assess shielding effectiveness.

Low Energy Gamma Detector for contamination surveys.

SPECIAL PRECAUTIONS

- Store ^{111}In behind ¼-inch [~ 0.6 cm] thick lead (Pb) shielding.
- Use tools to indirectly handle unshielded sources and potentially contaminated vessels; avoid direct hand contact.
- Ensure that an appropriate, operational survey meter (e.g. Bicron PGM) is present in the work area and turned on whenever ^{111}In is handled, so that any external exposure issues will be immediately apparent and hence quickly addressed.
- Shield waste containers as needed to maintain accessible dose rate ALARA and < 2 mR/hr.

GENERAL PRECAUTIONS

1. Maintain your occupational exposure to radiation As Low As Reasonably Achievable [ALARA].
2. Ensure all persons handling radioactive material are trained, registered, & listed on an approved protocol.
3. Review the nuclide characteristics on (reverse side) prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the responsible Principal Investigator to view the protocol information.
4. Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce internal and external radiation dose by monitoring the worker and the work area after each use of radioactive material, then promptly cleaning up any contamination discovered. Use the smallest amount of radioisotope possible so as to minimize radiation dose and radioactive waste.
5. Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal. Perform and record regular lab surveys.
6. Provide for safe disposal of radioactive waste by following institutional Waste Handling & Disposal Procedures. Avoid generating mixed waste (combinations of radioactive, biological, and chemical waste). Note that lab staff may not pour measurable quantities of radioactive material down the drain.
7. If there is a question regarding any aspect of the radiation safety program or radioactive material use, contact Radiation Safety.

LAB PRACTICES

1. Disposable gloves, lab coats, and safety glasses are the minimum PPE [Personal Protective Equipment] required when handling radioactive material. Remove & discard potentially contaminated PPE prior to leaving the area where radioactive material is used.
2. Clearly outline radioactive material use areas with tape bearing the legend "radioactive". Cover lab bench tops where radioactive material will be handled with plastic-backed absorbent paper; change this covering periodically and whenever it's contaminated. Alternatively cover benches with thick plastic sheeting (i.e., painter’s drop cloth), periodically wipe it clean and replace it if torn.
3. Label each unattended radioactive material container with the radioactive symbol, isotope, activity, and, except for waste, the ICN [inventory control number]. Place containers too small for such labels in larger labeled containers.
4. Handle radioactive solutions in trays large enough to contain the material in the event of a spill.
5. Never eat, drink, smoke, handle contact lenses, apply cosmetics, or take/apply medicine in the lab; keep food, drinks, cosmetics, etc. out of the lab entirely. Do not pipette by mouth.
6. Never store [human] food and beverage in refrigerators/freezers used for storing radioisotopes.
7. Prevent skin contact with skin-absorbable solvents containing radioactive material.
8. Fume hoods and biological safety cabinets for use with non-airborne radioactive material must be approved (through the protocol) and must be labeled "Caution Radioactive Material".
9. All volatile, gaseous, or aerosolized radioactive material must be used only in a properly operating charcoal and/or HEPA filtered fume hood or Biological Safety Cabinet bearing a Caution Airborne Radioactivity hood label, unless otherwise specified in writing by the Radiation Safety Officer. In particular, radioactive iodination must be performed only in these specially designed fume hoods. The Radiation Safety Officer (through a protocol) must approve all such use.
10. Take special precautions when working with radioactive compounds that tend to become volatile [e.g. ^{35}S labeled amino acids, ^{125}I - iodine tends to volatilize in acidic solutions], such as: use the materials only within an approved fume hood; protect the house vacuum system with primary & secondary vapor trapping devices; and cover active cell cultures with carbon-impregnated paper.
11. Use sealed containers and appropriate secondary containment to carry radioactive material between rooms. Notify Radiation Safety staff before taking any radioactive material off site.

^{124}I
Iodine-124

PHYSICAL DATA

Radiation: Betas – 1532 keV (11%); 2135 keV (11%)
Gamma & X-ray – 511 keV (46%); 603 keV (61%); 1691 keV (11%); others
Gamma Constant: 7.6E-1 mrem/hr per mCi @ 1.0 meter [2.05E-4 mSv/hr per MBq @ 1.0 meter]
Half-Life [$T_{½}$: Physical $T_{½}$: 4.18 days
Biological $T_{½}$: 120-138 days (unbound iodine)
Effective $T_{½}$: ~ 4 days (unbound iodine)

Specific Activity: 2.5E5 Ci/g [9.32E15 Bq/g] max.

RADIOLOGICAL DATA

Radiotoxicity: 2.82E-7 Sv/Bq (1.04E3 mrem/uCi) of ^{124}I ingested [Thyroid] 1.69E-7 Sv/Bq (6.25E2 mrem/uCi) of ^{124}I inhaled [Thyroid]
Critical Organ: Thyroid Gland

Intake Routes: Ingestion, inhalation, puncture, wound, skin contamination (absorption); Radiological Hazard: External & Internal Exposure; Contamination

SHIELDING

Lead [Pb]

Half Value Layer [HVL]	Tenth Value Layer [TVL]
8 mm (0.31 inches)	31 mm (1.22 inches)

The accessible dose rate should be background but must be < 2 mR/hr.

DOSIMETRY MONITORING

Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{124}I.
Conduct a baseline thyroid scan prior to first use of radioactive iodine.
Conduct thyroid bioassay measurement [at neck just above collar bone] no earlier than 6 hours but within 72 hours of handling 1 mCi (37 MBq) or more of ^{124}I or after any suspected intake.

DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller [e.g. Bicron PGM] to assess shielding effectiveness
Low Energy Gamma Detector [e.g. Ludlum 44-21] for contamination surveys
Wipe Test: Liquid Scintillation Counter

SPECIAL PRECAUTIONS

Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]
Use shielding [lead or leaded Plexiglas] to minimize exposure while handling mCi quantities of ^{124}I
Avoid making low pH [acidic] solutions containing ^{124}I to avoid volatilization.
For Iodination:

- Use a cannula adapter needle to vent stock vials of ^{124}I used; this prevents puff releases

- Cover test tubes used to count or separate fractions from iodination with Para film or other tight caps to prevent release while counting or moving outside the fume hood.

PRECAUTIONS

- Maintain your occupational exposure to radiation As Low As Reasonably Achievable [ALARA].
- Ensure all persons handling radioactive material are trained, registered, & listed on an approved protocol.
- Review the nuclide characteristics on (reverse side) prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the responsible Principal Investigator to view the protocol information.
- Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce internal and external radiation dose by monitoring the worker and the work area after each use of radioactive material, then promptly cleaning up any contamination discovered. Use the smallest amount of radioisotope possible so as to minimize radiation dose and radioactive waste.
- Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal. Perform and record regular lab surveys.
- Provide for safe disposal of radioactive waste by following institutional Waste Handling & Disposal Procedures. Avoid generating mixed waste (combinations of radioactive, biological, and chemical waste). Note that lab staff may not pour measurable quantities of radioactive material down the drain.
- If there is a question regarding any aspect of the radiation safety program or radioactive material use, contact Radiation Safety.

LAB PRACTICES

- Disposable gloves, lab coats, and safety glasses are the minimum PPE [Personal Protective Equipment] required when handling radioactive material. Remove & discard potentially contaminated PPE prior to leaving the area where radioactive material is used.
- Clearly outline radioactive material use areas with tape bearing the legend "radioactive". Cover lab bench tops where radioactive material will be handled with plastic-backed absorbent paper. change this covering periodically and whenever it's contaminated. Alternatively cover benches with thick plastic sheeting (i.e., painter's drop cloth), periodically wipe it clean and replace it if torn.
- Label each unattended radioactive material container with the radioactive symbol, isotope, activity, and, except for waste, the ICN [inventory control number]. Place containers too small for such labels in larger labeled containers.
- Handle radioactive solutions in trays large enough to contain the material in the event of a spill.
- Never eat, drink, smoke, handle contact lenses, apply cosmetics, or take/apply medicine in the lab; keep food, drinks, cosmetics, etc. out of the lab entirely. Do not pipette by mouth.
- Never store [human] food and beverage in refrigerators/freezers used for storing radioisotopes.
- Prevent skin contact with skin-absorbable solvents containing radioactive material.
- Fume hoods and biological safety cabinets for use with non-airborne radioactive material must be approved (through the protocol) and must be labeled "Caution Radioactive Material".
- All volatile, gaseous, or aerosolized radioactive material must be used only in a properly operating charcoal and/or HEPA filtered fume hood or Biological Safety Cabinet bearing a Caution Airborne Radioactivity hood label, unless otherwise specified in writing by the Radiation Safety Officer. In radioactive iodination must be performed only in these specially designed fume hoods. The Radiation Safety Officer (through a protocol) must approve all such use.
- Take special precautions when working with radioactive compounds that tend to become volatile [e.g. ^{35}S labeled amino acids, ^{125}I - iodine tends to volatilize in acidic solutions]. These precautions may include using the materials only within an approved fume hood, protecting the house vacuum system with primary and secondary vapor trapping devices, and covering active cell cultures with carbon-impregnating paper.

- Use sealed containers and appropriate secondary containment to carry radioactive material between rooms Notify Radiation Safety staff before taking any radioactive material off site.

^{18}F

Flourine-18

PHYSICAL DATA

Radiation: Gamma: 511 keV (194% abundance; positron annihilation radiation) Betas: 634 keV (97% abundance) [Positron]

Gamma Constant: 1.879E-04 mSv/hr per MBq at 1 meter[1] [6.952E-4 mrem/hr per uCi at 1 m]

Half-Life [T½]: Physical T½: 1.83 hours

Biological T½: ~ 6 hours

Effective T½: ~ 1hours

Specific Activity: 9.51E7 Ci/g [3.52E18Bq/g]

RADIOLOGICAL DATA

Radiotoxicity: Ingested: 2.9E-10 Sv/Bq [1.1 mrem/uCi] stomach wall
3.31E-11 Sv/Bq [0.12 mrem/uCi]
CEDE Inhaled: 1.4E-10 Sv/Bq [0.52 mrem/uCi] Lung
2.3E-11 Sv/Bq [0.084 mrem/uCi] CEDE

Critical Organ: Lung (inhalation); stomach wall (ingestion)

Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination absorption Radiological Hazard: External & Internal Exposure; Contamination

SHIELDING

Gamma:	Half Value Layer (HVL)	Tenth Value Layer (TVL)
Lead [Pb]	6 mm	17 mm

Beta Shielding: 1.7 mm plastic

- The accessible dose rate should be background but must be < 2 mR/hr.

DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{18}F.

DETECTION & MEASUREMENT

Portable Survey Meters, Geiger-Mueller [e.g. Bicron PGM] to assess shielding effectiveness Wipe Test: Gamma Counter, Gamma Well Counter, or Liquid Scintillation Counter (wipes must be run soon after sample collection due to short half-life).

SPECIAL PRECAUTIONS

- Store ^{18}F behind lead (Pb) shielding.
- Use tools to indirectly handle unshielded sources and potentially contaminated vessels; avoid direct hand contact.

- Ensure that an appropriate, operational survey meter (e.g. Bicron PGM) is present in the work area and turned on whenever ^{18}F is handled, so that any external exposure issues will be immediately apparent and hence quickly addressed.
- Shield waste containers as needed to maintain accessible dose rate ALARA and < 2 mR/hr
- ^{18}F has short half-life (109.8 minutes) makes rigorous inventory tracking unnecessary. Also, storage for decay can normally be accomplished at the point of use, since ^{18}F compounds will decay to
background levels within a day or two.

GENERAL PRECAUTIONS

- Maintain your occupational exposure to radiation As Low As Reasonably Achievable [ALARA].
- Ensure all persons handling radioactive material are trained, registered, & listed on an approved protocol.
- Review the nuclide characteristics on (reverse side) prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the responsible Principal Investigator to view the protocol information.
- Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce internal and external radiation dose by monitoring the worker and the work area after each use of radioactive material, then promptly cleaning up any contamination discovered. Use the smallest amount of radioisotope possible so as to minimize radiation dose and radioactive waste.
- Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal. Perform and record regular lab surveys.
- Provide for safe disposal of radioactive waste by following institutional Waste Handling & Disposal Procedures. Avoid generating mixed waste (combinations of radioactive, biological, and chemical waste). Note that lab staff may not pour measurable quantities of radioactive material down the drain.
- If there is a question regarding any aspect of the radiation safety program or radioactive material use, contact Radiation Safety.

LAB PRACTICES

-Disposable gloves, lab coats, and safety glasses are the minimum PPE [Personal Protective Equipment] required when handling radioactive material. Remove & discard potentially contaminated PPE prior to leaving the area where radioactive material is used.
-Clearly outline radioactive material use areas with tape bearing the legend "radioactive". Cover lab bench tops where radioactive material will be handled with plastic-backed absorbent paper; change this covering periodically and whenever it's contaminated. Alternatively cover benches with thick plastic sheeting (i.e., painter's drop cloth), periodically wipe it clean and replace it if torn.
-Label each unattended radioactive material container with the radioactive symbol, isotope, activity, and, except for waste, the ICN [inventory control number]. Place containers too small for such labels in larger labeled containers.
-Handle radioactive solutions in trays large enough to contain the material in the event of a spill.
-Never eat, drink, smoke, handle contact lenses, apply cosmetics, or take/apply medicine in the lab; keep food, drinks, cosmetics, etc. out of the lab entirely. Do not pipette by mouth.
-Never store [human] food and beverage in refrigerators/freezers used for storing radioisotopes.
-Prevent skin contact with skin-absorbable solvents containing radioactive material.
-Fume hoods and biological safety cabinets for use with non-airborne radioactive material must be approved (through the protocol) and must be labeled "Caution Radioactive Material".

-All volatile, gaseous, or aerosolized radioactive material must be used only in a properly operating charcoal and/or HEPA filtered fume hood or Biological Safety Cabinet bearing a Caution Airborne Radioactivity hood label, unless otherwise specified in writing by the Radiation Safety Officer. In particular, radioactive iodination must be performed only in these specially designed fume hoods.
The Radiation Safety Officer (through a protocol) must approve all such use.
-Take special precautions when working with radioactive compounds that tend to become volatile [e.g. ^{35}S labeled amino acids, ^{125}I - iodine tends to volatilize in acidic solutions]. These precautions may include using the materials only within an approved fume hood, protecting the house vacuum system with primary and secondary vapor trapping devices, and covering active cell cultures with carbon-impregnating paper.
-Use sealed containers and appropriate secondary containment to carry radioactive material between rooms Notify Radiation Safety staff before taking any radioactive material off site.

^{64}Cu
Copper-64

PHYSICAL DATA

Radiation: Gamma & X-ray: 511 keV (36% abundance), 7-8 keV (34% abundance)
Betas: 578 keV (37% abundance), 653 keV positron (18% abundance)
Gamma Constant: 3.6E-5 mSv/hr per MBq at 1 m (0.133 mrem/hr per mCi @ 1m)

Half-Life [T½]: Physical T½: 12.7 hours
Biological T½: ~ 7 days
Effective T½: ~ 11.8 hours

Specific Activity: 3.86E6 Ci/g [1.43E17 Bq/g]

RADIOLOGICAL DATA

Radiotoxicity: 0.466 mrem/uCi [1.26E-10 Sv/Bq] of ^{64}Cu ingested [CEDE]
0.277 mrem/uCi [7.48E-11 Sv/Bq] of ^{64}Cu inhaled [CEDE]
Critical Organ: Lung (inhalation)
Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination/absorption
Radiological Hazard: External & Internal Exposure; Contamination

SHIELDING

	Half Value Layer (HVL)	Tenth Value Layer (TVL)
Lead [Pb]	6 mm	17 mm

- The accessible dose rate should be background but must be < 2 mR/hr.

DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{64}Cu.
- Submit a urine sample to Radiation Safety 2 to 24 hours [i.e. As Soon As Possible] after any suspected intake of ^{64}Cu; alert Radiation Safety of the short half-lived nuclide involved.

DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller [e.g. Bicron PGM] to assess shielding effectiveness.
Low Energy Gamma Detector [e.g. Ludlum 44-21] for contamination surveys

Wipe Test: Gamma Counter, Well Gamma Counter, or Liquid Scintillation Counter

SPECIAL PRECAUTIONS

- Store ^{64}Cu behind 2 inch [~5 cm] thick lead (Pb) bricks.
- Use tools to indirectly handle unshielded sources and potentially contaminated vessels; avoid direct hand contact.
- Ensure that an appropriate, operational survey meter (e.g. Bicron PGM) is present in the work area and turned on whenever ^{64}Cu is handled, so that any external exposure issues will be immediately apparent and hence quickly addressed.
- Shield waste containers as needed to maintain accessible dose rate ALARA and < 2 mR/hr.

GENERAL PRECAUTIONS

- Maintain your occupational exposure to radiation As Low As Reasonably Achievable [ALARA].
- Ensure all persons handling radioactive material are trained, registered, & listed on an approved protocol.
- Review the nuclide characteristics on (reverse side) prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the responsible Principal Investigator to view the protocol information.
- Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce internal and external radiation dose by monitoring the worker and the work area after each use of radioactive material, then promptly cleaning up any contamination discovered. Use the smallest amount of radioisotope possible to minimize radiation dose and radioactive waste.
- Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal. Perform and record regular lab surveys.
- Provide for safe disposal of radioactive waste by following institutional Waste Handling & Disposal Procedures. Avoid generating mixed waste (combinations of radioactive, biological, and chemical waste). Note that lab staff may not pour measurable quantities of radioactive material down the drain.
- If there is a question regarding any aspect of the radiation safety program or radioactive material use, contact Radiation Safety.

LABORATORY PRACTICES

- Disposable gloves, lab coats, and safety glasses are the minimum PPE [Personal Protective Equipment] required when handling radioactive material. Remove & discard potentially contaminated PPE prior to leaving the area where radioactive material is used.
- Clearly outline radioactive material use areas with tape bearing the legend "radioactive". Cover lab bench tops where radioactive material will be handled with plastic-backed absorbent paper; change this covering periodically and whenever it's contaminated. Alternatively cover benches with thick plastic sheeting (i.e., painter's drop cloth), periodically wipe it clean and replace it if torn.
- Label each unattended radioactive material container with the radioactive symbol, isotope, activity, and, except for waste, the ICN [inventory control number]. Place containers too small for such labels in larger labeled containers.
- Handle radioactive solutions in trays large enough to contain the material in the event of a spill.
- Never eat, drink, smoke, handle contact lenses, apply cosmetics, or take/apply medicine in the lab; keep food, drinks, cosmetics, etc. out of the lab entirely. Do not pipette by mouth.
- Never store [human] food and beverage in refrigerators/freezers used for storing radioisotopes.
- Prevent skin contact with skin-absorbable solvents containing radioactive material.

- Fume hoods and biological safety cabinets for use with non-airborne radioactive material must be approved (through the protocol) and must be labeled "Caution Radioactive Material".
- All volatile, gaseous, or aerosolized radioactive material must be used only in a properly operating charcoal and/or HEPA filtered fume hood or Biological Safety Cabinet bearing a" Caution Airborne Radioactivity" hood label, unless otherwise specified in writing by the Radiation Safety Officer. In particular, radioactive iodination must be performed only in these specially designed fume hoods.
- The Radiation Safety Officer (through a protocol) must approve all such use.
- Take special precautions when working with radioactive compounds that tend to become volatile [e.g. ^{35}S labeled amino acids, ^{125}I - iodine tends to volatilize in acidic solutions]. These precautions may include using the materials only within an approved fume hood, protecting the house vacuum system with primary and secondary vapor trapping devices, and covering active.
  cell cultures with carbon-impregnating paper.
- Use sealed containers and appropriate secondary containment to carry radioactive material between rooms Notify Radiation Safety staff before taking any radioactive material off site.

^{177}Lu
Lutetium-177

I. PHYSICAL DATA

Radiation: Betas: 490 keV
Gamma & X-ray: 113 keV (3%), 210 keV (11%)
Gamma Constant: 0.028 mrem/hr per mCi @ 1.0 meter [7.636E-6 mSv/hr per MBq @ 1.0 meter]
Half-Life [T½]: Physical T½: 6.73 days, 6.65 days
Biological T½: GI: ~1 d; Lungs: ~30 d; Incorporated fraction (<10%): ~4 y
Effective T½: GI: ~0.9 d; Lungs: ~6 d; Incorporate fraction (<10%): ~6.7 d
Specific Activity: 1.1E5 Ci/g [4.1E15 Bq/g] max.

II. RADIOLOGICAL DATA

Radiotoxicity: 6.43E-9 Sv/Bq (2.38 mrem/uCi) of ^{177}Lu ingested [LLI]
3.33E-9 Sv/Bq (1.12 mrem/uCi) of ^{177}Lu inhaled [lung]
Critical Organ: Lower Large Intestine (ingestion); Lung (inhaled)
Intake Routes: Ingestion, inhalation, puncture, wound, skin contamination (absorption);
Radiological Hazard: External & Internal Exposure; Contamination

III. SHIELDING

Photons:
Lead [Pb]

	Half Value Layer [HVL]	Tenth Value Layer [TVL]
	0.6 mm (0.02 inches)	2.1 mm (0.08 inches)

Betas: 0.135 cm Plexiglas
- The accessible dose rate should be background but must be < 2 mR/hr.

IV. DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{177}Lu.

V. DETECTION & MEASUREMENT

Portable Survey Meters:
Geiger-Mueller [e.g. Bicron PGM] to assess shielding effectiveness.
Low Energy Gamma Detector [e.g. Ludlum 44-21] for contamination surveys
Wipe Test: Liquid Scintillation Counter

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake].

VII. GENERAL PRECAUTIONS

1. Maintain your occupational exposure to radiation As Low As Reasonably Achievable [ALARA].
2. Ensure all persons handling radioactive material are trained, registered, & listed on an approved

protocol.
3. Review the nuclide characteristics on (reverse side) prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the responsible Principal Investigator to view the protocol information.
4. Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce internal and external radiation dose by monitoring the worker and the work area after each use of radioactive material, then promptly cleaning up any contamination discovered. Use the smallest amount of radioisotope possible so as to minimize radiation dose and radioactive waste.
5. Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal. Perform and record regular lab surveys.
6. Provide for safe disposal of radioactive waste by following institutional Waste Handling & Disposal Procedures. Avoid generating mixed waste (combinations of radioactive, biological, and chemical waste). Note that lab staff may not pour measurable quantities of radioactive material down the drain.
7. If there is a question regarding any aspect of the radiation safety program or radioactive material use, contact Radiation Safety.

VIII. LAB PRACTICES

1. Disposable gloves, lab coats, and safety glasses are the minimum PPE [Personal Protective Equipment] required when handling radioactive material. Remove & discard potentially contaminated PPE prior to leaving the area where radioactive material is used.
2. Clearly outline radioactive material use areas with tape bearing the legend "radioactive". Cover lab bench tops where radioactive material will be handled with plastic-backed absorbent paper. change this covering periodically and whenever it's contaminated. Alternatively cover benches. with thick plastic sheeting (i.e., painter’s drop cloth), periodically wipe it clean and replace it if torn.
3. Label each unattended radioactive material container with the radioactive symbol, isotope, activity, and, except for waste, the ICN [inventory control number]. Place containers too small for such labels in larger labeled containers.
4. Handle radioactive solutions in trays large enough to contain the material in the event of a spill.
5. Never eat, drink, smoke, handle contact lenses, apply cosmetics, or take/apply medicine in the lab. keep food, drinks, cosmetics, etc. out of the lab entirely. Do not pipette by mouth.
6. Never store [human] food and beverage in refrigerators/freezers used for storing radioisotopes.
7. Prevent skin contact with skin-absorbable solvents containing radioactive material.
8. Fume hoods and biological safety cabinets for use with non-airborne radioactive material must be approved (through the protocol) and must be labeled "Caution Radioactive Material".
9. All volatile, gaseous, or aerosolized radioactive material must be used only in a properly operating charcoal and/or HEPA filtered fume hood or Biological Safety Cabinet bearing a Caution Airborne Radioactivity hood label, unless otherwise specified in writing by the Radiation Safety Officer. In particular, radioactive iodination must be performed only in these specially designed fume hoods. The Radiation Safety Officer (through a protocol) must approve all such use.
10. Take special precautions when working with radioactive compounds that tend to become volatile [e.g. $_{35}$S labeled amino acids, $_{125}$I - iodine tends to volatilize in acidic solutions]. These precautions may include using the materials only within an approved fume hood, protecting the house vacuum system with primary and secondary vapor trapping devices, and covering active cell cultures with carbon-impregnating paper.
11. Use sealed containers and appropriate secondary containment to carry radioactive material between rooms Notify Radiation Safety staff before taking any radioactive material off site.

APPENDIX D

IODINATION SAFETY TIPS

Iodinations are performed commonly at WSU; however, with safe practices exposures do not occur. Air monitoring may be done during iodination by OEHS to assure that room air is not contaminated. Additionally, bioassays detect any uptakes which may occur. These bioassays are required for all workers performing iodination.

Iodination labeling, however, can create potential exposures to the thyroid in workers if proper safety precautions are not followed explicitly. ^{125}I in the $Na^{125}I$ chemical form is volatile, and exposure through inhalation routes can occur. Most iodinations are done with quantities of 1.0 mCi or greater, so very little airborne release of this concentrated material may cause a significant ^{125}I uptake.

The following list of safety precautions will assist workers in preventing unnecessary exposures to ^{125}I during iodination. If you have questions, or would like assistance in iodination procedures, please call 7-1253.

1. All iodination and use of $Na^{125}I$ must be conducted in a fume hood certified for radioisotope use. Work should be done at least 6 inches back from the front of the fume hood. Fume hoods should be free of clutter, and large objects should be placed on blocks to elevate them 2 inches from the floor of the fume hood. The sash of the fume hood should be brought down to the lowest possible height while still maintaining ample room for manual dexterity.
2. The fume hood should be covered with poly-backed absorbent paper to absorb possible spills, drips or airborne activity.
3. Double gloves should be worn. Latex or N-Dex gloves are preferable because they have a tighter fit, allowing good dexterity while wearing two or three pairs.
4. Poly-backed absorbent paper should be taped to the floor in front of the fume hood to prevent contamination and spreading in the event of an accidental spill or release.
5. Lab coats and film badges must be worn.
6. A survey meter with a low energy gamma probe must be used during the iodination. It should be placed near the iodination hood (not inside the hood) with the audio on. A noticeable and substantial change in the audible count rate during the iodination is an indicator that will alert the worker to possible release from the fume hood. Procedures should then be implemented to prevent further release into the breathing air in the room. Call the OEHS for advice on handling the situation.
7. To remove the $Na^{125}I$ from the shipping vial, use an adapter to provide a conduit for the syringe used to withdraw the aliquot. A short 16-gauge cannula needle, available from General Stores, makes an excellent adapter. This prevents the syringe needles from bending, thus avoiding possible skin punctures while venting fumes before withdrawing the solution.
8. Mix the reaction vial with a gentle tapping motion rather than shaking. Fumes are released in higher quantities with vigorous mixing; gently tap the reaction tube to provide gentle mixing. Hold the vial well up inside the hood so that fumes are drawn up through the hood, rather than into the room air.
9. NEVER collect iodination fractions outside the fume hood. High amounts of free iodine are contained in these fractions, and intakes can occur if the tubes are not collected in the hood.
10. NEVER count fractions from iodination in tubes or vials which are not tightly capped. Dispose of counting tubes or vials with caps on in the iodination waste, not in the regular ^{125}I waste.
11. Contain all waste from the iodination as it is generated. Have plastic waste bags in the fume hood in an accessible location for dry waste. Liquid waste should be deposited in plastic bottles with screw-top caps to contain release. When the iodination is finished, place both dry and liquid waste in double zip lock plastic bags and label the waste with radioactive waste tags. Denote "Free ^{125}I" on the waste tag.
12. Store all syringes, glassware and other equipment that is reused in the iodination fume hood between uses. Label all iodination equipment thoroughly.

13. Thyroid scans must be performed on workers after each iodination. A baseline thyroid scan is done to determine a background for each iodinater prior to conducting iodination at WSU. Post-iodination thyroid scans are done no less than 6 hours and no more than 72 hours after the iodination. Thyroid scans are required by law, and not obtaining them may cause a violation of our NRC license conditions. Call the OEHS to obtain a thyroid scan.
14. If a spill occurs inside the fume hood during an iodination, close the hood sash completely. If a spill occurs outside the fume hood, place absorbent on the spill and evacuate personnel from the room. Call the OEHS immediately to notify that the spill has occurred.
15. After every iodination, thoroughly survey the entire area, including floors, hood, equipment, outer waste container surfaces, hands, feet and clothing.

EMERGENCY PROCEDURES FOR FREE ^{125}I ACCIDENT

In the event of an accident with free iodine outside the hood, don't panic. Immediately get everyone out of the room. If possible, grab the survey meter on your way out. To minimize the spread of contamination, the people involved should go to a predetermined location and close the door. (A desirable location would have available a telephone, sink, hood and be in a "low traffic" area. The hallway outside the room may be the only choice if there are no adjacent rooms with closing doors.)

It is recommended that some disposable lab matting or other absorbent paper be placed on the floor for people to stand on, until they can be surveyed and found free of contamination or decontaminated. If you have any contamination on your skin, wash it off. If your clothing is contaminated, remove the affected articles and place in the hood. Be sure the hood is turned on.

During regular workdays and hours call the OEHS at (57)7-1200 and request to speak to a health physics staff member. Tell the person answering the phone that you are reporting a radiation emergency. Then call your PI and let him/her know exactly what has happened and what you have done thus far.

If an accident occurs after regular working hours, dial (57)7-2222, tell the dispatcher that you have a radiation emergency and need Radiation Safety assistance. (They will call the OEHS emergency pager.) Be prepared to provide the following information:

1. Medical services required, if any (paramedics, ambulance)
2. Your name
3. Building name and room number
4. Your phone number - where you can be reached
5. Name of lab's principal investigator
6. Isotope involved
7. Chemical form of isotope or say it is an iodination accident
8. Estimation of amount of activity involved
9. Number of people involved
10. What has been done thus far

Then call your PI, if possible, and give the same information.

APPENDIX E

Properties of Some Commonly Used Beta Emitters

Property	^{3}H	^{14}C	^{45}Ca	^{32}P	^{90}Sr
Half Life	12.3y	5730y	163d	14.3d	28.1y
Max beta energy (MeV)	0.0186	0.156	0.257	1.71	2.27[a]
Average beta energy (MeV)	0.006	0.049	0.077	0.70	1.13[b]
Range (cm) in unit density material	0.00052	0029	0.06	0.8	1.1
HVL (cm), unit density absorber	----	0.0022	0.0048	1.10	0.14
Dose rate from 100 beta particles/cm^{2}sec-^{1} (mRad/hr)[c]	----	56	33	11	11
Fraction transmitted through dead layer of skin (0.007 cm)	----	0.11	0.37	0.95	0.97
Dose rate (mRad/hr) to basal cells[d] of epidermis per mCi/cm^2	----	1,400	4,000	9,200	17,000

a. From the ^{90}Y decay product. ^{90}Sr emits 0.55 MeV (max) beta.
b. ^{90}Sr (0.196) + ^{90}Y (0.93).
c. The dose rate for 100 b particles/cm 2 -sec is for a parallel beam.
d. The dose rate to basal cells of the epidermis is from beta particles emitted in all directions equally from contamination on the surface of the skin. Basal cells are considered to be 0.007 cm below the surface.
e. The dose rate to basal cells of the epidermis listed for ^{90}Sr includes the ^{90}Y contribution. Data for half-lives and maximum and average beta energies taken from MIRD, 1975.

(J. Shapiro, *Radiation Protection--A Guide for Scientists and Physicians*)

Tissue Dose Rate (rads/hr) at Various Distances Around a 1 uCi Particle of Various Beta Emitters (Range in Tissue 1 - 10 mm.) um mm

Um	Mm	^{14}C	^{90}Sr	^{32}P	^{90}Y
10	--	2,000,000	530,000	380,000	270,000
100	0.1	1,500	5,000	3,700	2,700
200	0.2	40	1,100	930	680
400	0.4	0.03	200	230	160
600	0.6	0	60	100	70
1,000	1.0	0	10	30	26
10,000	10.0	0	0	0	0.02

(From NATO AMedP-6, Part 1, 1973)

APPENDIX L

Wayne State University
Laboratory Specific Training Form

Checklist for Worker Training in Radiation Laboratories

This form needs to be filled by workers who may use radioactive material and or x-ray generating machines. It should be signed by the principal investigator and the radiation worker. Please put an X in the box next to those items you have completed and NA in those not applicable to you. Please do not leave the space blank.

This form is to be kept in the record binder for the laboratory you are working in.

Using - Radioactive Material – complete this section **X or NA**

1.	I have attended and passed the in-classroom Basic Radiation Safety Course.	
2.	I have read and understood the Radiation Safety Manual and/or Radiation Safety Lab Guide	
3.	I have been instructed on the radioisotopes used in my laboratory.	
4.	I have been instructed on the specific security measures relating to radioactive materials in the lab. Example: Locking the refrigerator, freezer, or room when no one is present in the lab.	
5.	I have been instructed on the specific procedures for the handling of radioactive waste in my lab.	
6.	I understand in the case of an emergency that I notify WSU police at 313-577-2222	

Using - X-ray generating equipment – complete this section **X or NA**

1.	I have taken the online Radiation Generating Machine training.	
2.	I have been instructed on the proper use of all x-ray generating equipment that I may operate, including start up, proper function of interlocks, and general procedures for use.	
3.	I understand in case of any emergency that I notify WSU police at 313-577-2222.	

Worker consent: I certify that I have been provided with and understand the information indicated above. I understand that this is a certification of principle investigator training. I understand that I am responsible for adhering to all safety practices, laws, rules, and guidelines.

____

Worker – Print name ***Worker – Signature*** ***Date***

Principal Investigator: I certify that the above information was reviewed with or provided to the person named above worker.

____

Principal Investigator Signature ***Date***

INSTRUCTIONS FOR PRINCIPAL INVESTIGATORS REGARDING THE CHECKLIST FOR TRAINING WOKERS IN RADIATION LABORATORIES

1. Individuals frequenting an area where radioactive materials are used, stored or disposed should receive principal investigator training. This training must be documented with this checklist.

2. Training is function specific and site specific, meaning the content and depth of training is related to the duties of the person and the scope of the hazards present in the work area.

3. Exposure limits must be explained to workers. For persons who are not certified radiation workers, the exposure limits are General Public, or 100 mrem per year. For radiation workers, the limits are the occupational limits set forth in the 10 CFR 20 laws, or 5 rem per year TEDE (whole body), 50 rem per year TODE (organ), 15 rem per year to the lens of the eye, 50 rem per year for the skin of the whole body and/or extremities. **Radiation workers must have received introductory safety training at the OEHS, and must attend annual refreshers for radiation and hazardous waste**.

4. Copies of the training records may be kept in the safety notebook.

5. Security and control of radioactive materials must be provided at all times, either with persons present or locking or securing to prevent tampering or unauthorized use or removal. Persons who are not radiation workers may provide this control if they are appropriately trained by the PI and/or the OEHS radiation safety training class.

6. This document serves as informed consent of the worker.

APPENDIX M

Contamination Survey Room Diagram Form

The following diagram must be completed to accurately represent the layout of the laboratory, including benches, sinks, hoods, refrigerators, freezers, waste containers, etc. This form is to be used in conjunction with the after-use and monthly survey forms provided and kept in the lab along with these records.

Approval Holder: ______________________ **Room Location:** ______________________

Please include and label each Bench, Hood, Floor, Refrigerator, or other unit numerically
i.e. B1, B2, B3, H1, H2, F1, F2, F3, R1, S1, W1, W2,... etc.

Date:____________________

APPENDIX N

Monthly Contamination Survey Form

The following form MUST be used for documenting the contamination surveys performed each month in every radioactive use lab. This record must be accompanied by the wipe test result printout, if performing wipes, and MUST correspond to the labeled areas of the room diagram of the lab in which the survey was
conducted.

Monthly Contamination Survey

Survey Date:	Building:	Room:	Approval Holder:
Surveyor: Last Name, First Name			Position / Title:

Please indicate use: ☐ Radionuclides were used this month ☐ Radionuclides were NOT used this month

Please indicate the total activity of each isotope used since the previous contamination survey

Isotope	Activity	Isotope	Activity
H-3		P-32	
C-14		I-125	
S-35		Cr-51	

Survey Results must be recorded in DPM
DPM = CPM/ Instrument Efficiency
Wipe Test printouts must be retained

Survey Method: Meter / Wipe		Survey Method: Meter / Wipe	
Nuclide(s):		Nuclide(s):	
Instrument model / location:		Instrument model / location:	
Area	Results (**DPM**)	Area	Results (**DPM**)
BKG		BKG	

Directions For Use: A **lab with any radioactive material must complete this entire form.** From your lab diagram, indicate areas of survey in boxes provided and the results in DPM in the adjacent box. Perform survey in all applicable locations respective to the lab size, setup and use, including an additional survey of the floor adjacent to each area. IN THE EVENT OF NON-USE YOU MUST PERFORM SURVEYS IN AT LEAST STORAGE AND WASTE AREAS. Circle which survey method will be used (Meter / Wipe) in the box provided. You must do both wipe testing and meter surveying if your lab contains one or more radionuclides requiring wipes AND one or more radionuclides requiring meter survey. Consult the Radiation Safety Manual for clarification or call Health Physics at 577-1200.

Action Limits:
Wipe: 220 DPM / 100 sq cm
Meter: 50 counts above background.

Remarks: Include actions taken for contamination found.

By signing below, the surveyor attests that he/she has read and understands the Radiation Safety Manual and its procedures and requirements for contamination surveys.

Surveyor 's Signature:

APPENDIX O
Please Retain the Wipe Test Result Printouts

Use Log and After-use Contamination Survey Form

Radioisotope   Lot Number   Delivery Date   Original Activity (uCi)   Assay Date   Chemical Form

Date	Name	Amount Used (uCi)	Amount Left (uCi)	Survey Method (Circle One)	Label of Areas Surveyed and Results (DPM)				
		0		Meter Wipe	Inner Vial =				
				Meter Wipe	BKG				
				Meter Wipe	BKG				
				Meter Wipe	BKG				
				Meter Wipe	BKG				
				Meter Wipe	BKG				
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Please Retain the Wipe Test Result Printouts

APPENDIX P

Regulatory Guide Concerning Prenatal Radiation Exposure

As discussed in Regulatory Guide 8.29, exposure to any level of radiation is assumed to carry with it a certain amount of risk. In the absence of scientific certainty regarding the relationship between low dose exposure and health effects, and as a conservative assumption for radiation protection purposes, the scientific community generally assumes that any exposure to ionizing radiation may cause undesirable biological effects and that the likelihood of these effects increases as the dose increases. At the occupational dose limit for the whole body of 5 rem (50 mSv) per year, the risk is believed to be very low.

The magnitude of risk of childhood cancer following in utero exposure is uncertain in that both negative and positive studies have been reported. The data from these studies "are consistent with a lifetime cancer risk resulting from exposure during gestation which is two to three times that for the adult" (NCRP Report No. 116). The NRC has reviewed the available scientific literature and has concluded that the 0.5 rem (5 mSv) limit specified in 10 CFR 20.1208 provides an adequate margin of protection for the embryo/fetus. This dose limit reflects the desire to limit the total lifetime risk of leukemia and other cancers associated with radiation exposure during pregnancy.

In order for a pregnant worker to take advantage of the lower exposure limit and dose monitoring provisions specified in 10 CFR Part 20, the woman must declare her pregnancy in writing to the licensee. A form letter for declaring pregnancy is provided in this guide or the licensee may use its own form letter for declaring pregnancy. A separate written declaration should be submitted for each pregnancy.

QUESTIONS AND ANSWERS CONCERNING PRENATAL RADIATION EXPOSURE

1. Why am I receiving this information?

   The NRC's regulations (in 10 CFR 19.12, "Instructions to Workers") require that licensees instruct individuals working with licensed radioactive materials in radiation protection as appropriate for the situation. The instruction below describes information that occupational workers and their supervisors should know about the radiation exposure of the embryo/fetus of pregnant women.

   The regulations allow a pregnant woman to decide whether she wants to formally declare her pregnancy to take advantage of lower dose limits for the embryo/fetus. This instruction provides information to help women make an informed decision whether to declare a pregnancy.

2. If I become pregnant, am I required to declare my pregnancy?

   No. The choice whether to declare your pregnancy is completely voluntary. If you choose to declare your pregnancy, you must do so in writing and a lower radiation dose limit will apply to your embryo/fetus. If you choose not to declare your pregnancy, you and your embryo/fetus will continue to be subject to the same radiation dose limits that apply to other occupational workers.

3. If I declare my pregnancy in writing, what happens?

   If you choose to declare your pregnancy in writing, the licensee must take measures to limit the dose to your embryo/fetus to 0.5 rem (5 millisievert) during the entire pregnancy. This is one-tenth of the dose that an occupational worker may receive in a year. If you have already received a dose exceeding 0.5 rem (5 mSv) in the period between conception and the declaration of your pregnancy, an additional dose of 0.05 rem (0.5 mSv) is allowed during the remainder of the pregnancy. In addition, 10 CFR 20.1208, "Dose to an Embryo/Fetus," requires licensees to make efforts to avoid substantial variation above a uniform monthly dose rate so that all the 0.5 rem (5 mSv) allowed dose does not occur in a short period during the pregnancy.

This may mean that, if you declare your pregnancy, the licensee may not permit you to do some of your normal job functions if those functions would have allowed you to receive more than 0.5 rem, and you may not be able to have some emergency response responsibilities.

4. <u>Why do the regulations have a lower dose limit for the embryo/fetus of a declared pregnant woman than for a pregnant worker who has not declared?</u>

   A lower dose limit for the embryo/fetus of a declared pregnant woman is based on a consideration of greater sensitivity to radiation of the embryo/fetus and the involuntary nature of the exposure. Several scientific advisory groups have recommended that the dose to the embryo/fetus be limited to a fraction of the occupational dose limit.

5. <u>What are the potentially harmful effects of radiation exposure to my embryo/fetus?</u>

   The occurrence and severity of health effects caused by ionizing radiation are dependent upon the type and total dose of radiation received, as well as the time period over which the exposure was received. See Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Exposure", for more information. The main concern is embryo/fetal susceptibility to the harmful effects of radiation such as cancer.

6. <u>Are there any risks of genetic defects?</u>

   Although radiation injury has been induced experimentally in rodents and insects, and in the experiments was transmitted and became manifest as hereditary disorders in their offspring, radiation has not been identified as a cause of such effect in humans. Therefore, the risk of genetic effects attributable to radiation exposure is speculative. For example, no genetic effects have been documented in any of the Japanese atomic bomb survivors, their children, or their grandchildren.

7. <u>What if I decide that I do not want any radiation exposure at all during my pregnancy?</u>

   You may ask your employer for a job that does not involve any exposure at all to occupational radiation dose, but your employer is not obligated to provide you with a job involving no radiation exposure. Even if you receive no occupational exposure at all, your embryo/fetus will receive some radiation dose (on average 75 mrem (0.75 mSv)) during your pregnancy from natural background radiation.

   The NRC has reviewed the available scientific literature and concluded that the 0.5 rem (5 mSv) limit provides an adequate margin of protection for the embryo/fetus. This dose limit reflects the desire to limit the total lifetime risk of leukemia and other cancers. If this dose limit is exceeded, the total lifetime risk of cancer to the embryo/fetus may increase incrementally. However, the decision on what level of risk to accept is yours. More detailed information on potential risk to the embryo/fetus from radiation exposure can be found in References 2-10.

8. What effect will formally declaring my pregnancy have on my job status?

   Only the licensee can tell you what effect a written declaration of pregnancy will have on your job status. As part of your radiation safety training, the licensee should tell you the company's policies with respect to the job status of declared pregnant women. In addition, before you declare your pregnancy, you may want to talk to your supervisor or your radiation safety officer and ask what a declaration of pregnancy would mean specifically for you and your job status.

   In many cases you can continue in your present job with no change and still meet the dose limit for the embryo/fetus. For example, most commercial power reactor workers (approximately 93%) receive, in 12 months, occupational radiation doses that are less than 0.5 rem (5 mSv). The licensee may also consider the likelihood of increased radiation exposures from accidents and abnormal events before making a decision to allow you to continue in your present job.

   If your current work might cause the dose to your embryo/fetus to exceed 0.5 rem (5 mSv), the licensee has various options. It is possible that the licensee can and will make a reasonable accommodation that will allow you to continue performing your current job, for example, by having another qualified employee do a small part of the job that accounts for some of your radiation exposure.

9. What information must I provide in my written declaration of pregnancy?

   You should provide, in writing, your name, a declaration that you are pregnant, the estimated date of conception (only the month and year need be given), and the date that you give the letter to the licensee. A form letter that you can use is included at the end of these questions and answers. You may use that letter, use a form letter the licensee has provided to you, or write your own letter.

10. To declare my pregnancy, do I have to have documented medical proof that I am pregnant?

    NRC regulations do not require that you provide medical proof of your pregnancy. However, NRC regulations do not preclude the licensee from requesting medical documentation of your pregnancy, especially if a change in your duties is necessary in order to comply with the 0.5 rem (5 mSv) dose limit.

11. Can I tell the licensee orally rather than in writing that I am pregnant?

    No. The regulations require that the declaration must be in writing.

12. If I have not declared my pregnancy in writing, but the licensee suspects that I am pregnant, do the lower dose limits apply?

    No. The lower dose limits for pregnant women apply only if you have declared your pregnancy in writing. The United States Supreme Court has ruled (in *United Automobile Workers International Union v. Johnson Controls, Inc*., 1991) that "Decisions about the welfare of future children must be left to the parents who conceive, bear, support, and raise them rather than to the employers who hire those parents" (Reference 7). The Supreme Court also ruled that your employer may not restrict you from a specific job "because of concerns about the next generation." Thus, the lower limits apply only if you choose to declare your pregnancy in writing.

13. If I am planning to become pregnant but am not yet pregnant and I inform the licensee of that in

writing, do the lower dose limits apply?

No. The requirement for lower limits applies only if you declare in writing that you are already pregnant.

14. What if I have a miscarriage or find out that I am not pregnant?

If you have declared your pregnancy in writing, you should promptly inform the licensee in writing that you are no longer pregnant. However, if you have not formally declared your pregnancy in writing, you need not inform the licensee of your nonpregnant status.

15. How long is the lower dose limit in effect?

The dose to the embryo/fetus must be limited until you withdraw your declaration in writing or you inform the licensee in writing that you are no longer pregnant. If the declaration is not withdrawn, the written declaration may be considered expired one year after submission.

16. If I have declared my pregnancy in writing, can I revoke my declaration of pregnancy even if I am still pregnant?

Yes, you may. The choice is entirely yours. If you revoke your declaration of pregnancy, the lower dose limit for the embryo/fetus no longer applies.

17. What if I work under contract at a licensed facility?

The regulations state that you should formally declare your pregnancy to the licensee in writing. The licensee has the responsibility to limit the dose to the embryo/fetus.

18. Where can I get additional information?

The references to this Appendix contain helpful information, especially Reference 3, NRC's Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Radiation Exposure," for general information on radiation risks. The licensee should be able to give this document to you.

Appendix P-1

FORM LETTER FOR DECLARING PREGNANCY

This form letter is provided for your convenience. To make your written declaration of pregnancy, you may fill in the blanks in this form letter, you may use a form letter the licensee has provided to you, or you may write your own letter.

DECLARATION OF PREGNANCY

To: ________________________

In accordance with the NRC's regulations at 10 CFR 20.1208, "Dose to an Embryo/Fetus," I am declaring that I am pregnant. I believe I became pregnant in_______________ (only the month and year need be provided).

I understand the radiation dose to my embryo/fetus during my entire pregnancy will not be allowed to exceed 0.5 rem (5 millisievert) (unless that dose has already been exceeded between the time of conception and submitting this letter). I also understand that meeting the lower dose limit may require a change in job or job responsibilities during my pregnancy.

____
(Your Signature)

____
(Your Name Printed)

____
(Date)

APPENDIX Q

INSTRUCTION CONCERNING RISKS FROM OCCUPATIONAL RADIATION EXPOSURE

This instructional material is intended to provide the user with the best available information about the health risks from occupational exposure to ionizing radiation. Ionizing radiation consists of energy or small particles, such as gamma rays and beta and alpha particles, emitted from radioactive materials, which can cause chemical or physical damage when they deposit energy in living tissue. A question-and-answer format is used. Many of the questions or subjects were developed by the NRC staff in consultation with workers, union representatives, and licensee representatives experienced in radiation protection training. This Revision 1 to Regulatory Guide 8.29 updates the material in the original guide on biological effects and risks and on typical occupational exposure. Additionally, it conforms to the revised 10 CFR Part 20, “Standards for Protection Against Radiation,” which was required to be implemented by licensees no later than January 1, 1994. The information in this appendix is intended to help develop respect by workers for the risks associated with radiation, rather than unjustified fear or lack of concern. Additional guidance concerning other topics in radiation protection training is provided in other NRC regulatory guides.

1. <u>What is meant by health risk?</u>

A health risk is generally thought of as something that may endanger health. Scientists consider health risk to be the statistical probability or mathematical chance that personal injury, illness, or death may result from some action. Most people do not think about health risks in terms of mathematics. Instead, most of us consider the health risk of a particular action in terms of whether we believe that particular action will, or will not, cause us some harm. The intent of this appendix is to provide estimates of, and explain the bases for, the risk of injury, illness, or death from occupational radiation exposure. Risk can be quantified in terms of the probability of a health effect per unit of dose received. When x-rays, gamma rays, and ionizing particles interact with living materials such as our bodies, they may deposit enough energy to cause biological damage. Radiation can cause several different types of events such as the very small physical displacement of molecules, changing a molecule to a different form, or ionization, which is the removal of electrons from atoms and molecules. When the quantity of radiation energy deposited in living tissue is high enough, biological damage can occur as a result of chemical bonds being broken and cells being damaged or killed. These effects can result in observable clinical symptoms.

The basic unit for measuring absorbed radiation is the rad. One rad (0.01 gray in the International System of units) equals the absorption of 100 ergs (a small but measurable amount of energy) in a gram of material such as tissue exposed to radiation. To reflect biological risk, rads must be converted to rems. The new international unit is the sievert (100 rems = 1 Sv). This conversion accounts for the differences in the effectiveness of different types of radiation in causing damage. The rem is used to estimate biological risk. For beta and gamma radiation, a rem is considered equal to a rad.

2. <u>What are the possible health effects of exposure to radiation?</u>

Health effects from exposure to radiation range from no effect at all to death, including diseases such as leukemia or bone, breast, and lung cancer. Very high (100s of rads), short-term doses of radiation have been known to cause prompt (or early) effects, such as vomiting and diarrhea, skin burns, cataracts & and even death. It is suspected that radiation exposure may be linked to the potential for genetic effects in the children of exposed parents. Also, children who were exposed to high doses (20 or more rads) of radiation prior to birth (as an embryo/fetus) have shown an increased risk of mental retardation and other congenital malformations. These effects (with the exception of genetic effects) have been observed in various studies of medical radiologists, uranium miners, radium workers, radiotherapy patients, and the people exposed to radiation from atomic bombs dropped on Japan. In addition, radiation effects studies with laboratory animals, in which the animals were given relatively high doses, have provided extensive data on radiation-induced health effects, including genetic effects. It is important to note that these kinds of health effects result from high doses, compared to occupational levels, delivered over a relatively short period of time. Although studies have not shown a consistent cause-and-effect relationship between current levels of occupational radiation exposure and biological effects, it is prudent from a worker protection perspective to assume that some effects may occur.

3. What is meant by early effects and delayed or late effects?

EARLY EFFECTS

Early effects, which are also called immediate or prompt effects, are those that occur shortly after a large exposure that is delivered within hours to a few days. They are observable after receiving a very large dose in a short period of time, for example, 300 rads (3 Gy) received within a few minutes to a few days. Early effects are not caused at the levels of radiation exposure allowed under the NRC's occupational limits. Early effects occur when the radiation dose is large enough to cause extensive biological damage to cells so that large numbers of cells are killed. For early effects to occur, this radiation dose must be received within a short time period. This type of dose is called an acute dose or acute exposure. The same dose received over a long time period would not cause the same effect. Our body's natural biological processes are constantly repairing damaged cells and replacing dead cells; if the cell damage is spread over time, our body is capable of repairing or replacing some of the damaged cells, reducing the observable adverse conditions. For example, a dose to the whole body of about 300-500 rads (3-5 Gy), more than 60 times the annual occupational dose limit, if received within a short time period (e.g., a few hours) will cause vomiting and diarrhea within a few hours; loss of hair, fever, and weight loss within a few weeks; and about a 50 percent chance of death if medical treatment is not provided. These effects would not occur if the same dose were accumulated gradually over many weeks or months. Thus, one of the justifications for establishing annual dose limits is to ensure that occupational dose is spread out in time. It is important to distinguish between whole body and partial body exposure. A localized dose to a small volume of the body would not produce the same effect as a whole-body dose of the same magnitude. For ex-ample, if only the hand were exposed, the effect would mainly be limited to the skin and underlying tissue of the hand. An acute dose of 400 to 600 rads (4-6 Gy) to the hand would cause skin reddening; recovery would occur over the following months and no long-term damage would be expected. An acute dose of this magnitude to the whole body could cause death within a short time without medical treatment, medical treatment would lessen the magnitude of the effects and the chance of death; however, it would not totally eliminate the effects or the chance of death.

DELAYED EFFECTS

Delayed effects may occur years after exposure. These effects are caused indirectly when the radiation changes parts of the cells in the body, which causes the normal function of the cell to change, for example, normal healthy cells turn into cancer cells. The potential for these delayed health effects is one of the main concerns addressed when setting limits on occupational doses. A delayed effect of special interest is genetic effects. Genetic effects may occur if there is radiation damage to the cells of the gonads (sperm or eggs). These effects may show up as genetic defects in the children of the exposed individual and succeeding generations. However, if any genetic effects (i.e., effects in addition to the normal expected number) have been caused by radiation, the numbers are too small to have been observed in human populations exposed to radiation. For example, the atomic bomb survivors (from Hiroshima and Nagasaki) have not shown any significant radiation-related increases in genetic defects. Effects have been observed in animal studies conducted at very high levels of exposure and it is known that radiation can cause changes in the genes in cells of the human body. However, it is believed that by maintaining worker exposures below the NRC limits and consistent with ALARA, a margin of safety is provided such that the risk of genetic effects is almost eliminated.

4. What is the difference between acute and chronic radiation dose?

Acute radiation dose usually refers to a large dose of radiation received in a short period of time. Chronic dose refers to the sum of small doses received repeatedly over long time periods, for example, 20 mrem (or millirem, which is l-thousandth of a rem) (0.2 mSv) per week every week for several years. It is assumed for radiation protection purposes that any radiation dose, either acute or chronic, may cause delayed effects. However, only large acute doses cause early effects; chronic doses within the occupational dose limits do not cause early effects. Since the NRC limits do not permit large acute doses, concern with occupational radiation risk is primarily focused on controlling chronic exposure for which possible delayed effects, such as cancer, are of concern. The difference between acute and chronic radiation exposure can be shown by using exposure to the sun's rays as an example. An intense exposure to the sun can result in painful burning, peeling, and growing of new skin, however, repeated short exposures provide time for the skin to be repaired between exposures. Whether exposure to the sun's rays is long term or spread over short periods, some of the injury may not be repaired and may eventually result in skin cancer. Cataracts are an interesting case because they can be caused by both acute and chronic radiation. A certain threshold level of dose to the lens of the eye is required before there is any observable visual impairment, and the impairment remains after the exposure is stopped. The threshold for cataract development from acute exposure is an acute dose on the order of 100 rads (1 Gy). Further, a cumulative dose of 800 rads (8 Gy) from protracted exposures over many years to the lens of the eye has been linked to some level of visual impairment. These doses exceed the amount that may be accumulated by the lens from normal occupational exposure under the current regulations.

5. <u>What is meant by external and internal exposure?</u>

A worker's occupational dose may be caused by exposure to radiation that originates outside the body, called "external exposure," or by exposure to radiation from radioactive material that has been taken into the body, called "internal exposure." Most NRC-licensed activities involve little, if any, internal exposure. It is the current scientific consensus that a rem of radiation dose has the same biological risk regardless of whether it is from an external or an internal source. The NRC requires that dose from external exposure and dose from internal exposure be added together, if each exceeds 10% of the annual limit, and that the total be within occupational limits. The sum of external and internal dose is called the total effective dose equivalent (TEDE) and is expressed in units of rems (Sv). Although unlikely, radioactive materials may enter the body through breathing, eating, drinking, or open wounds, or they may be absorbed through the skin. The intake of radioactive materials by workers is generally due to breathing contaminated air. Radioactive materials may be present as fine dust or gases in the workplace atmosphere. The surfaces of equipment and workbenches may be contaminated, and these materials can be re-suspended in air during work activities. If any radioactive material enters the body, the material goes to various organs or is excreted, depending on the biochemistry of the material. Most radioisotopes are excreted from the body in a few days. For example, a fraction of any uranium taken into the body will deposit in the bones, where it remains for a longer time. Uranium is slowly eliminated from the body, mostly by way of the kidneys. Most workers are not exposed to uranium. Radioactive iodine is preferentially deposited in the thyroid gland, which is located in the neck. To limit risk to specific organs and the total body, an annual limit on intake (ALI) has been established for each radionuclide. When more than one radionuclide is involved, the intake amount of each radionuclide is reduced proportionally. NRC regulations specify the concentrations of radioactive material in the air to which a worker may be exposed for 2,000 working hours in a year. These concentrations are termed the derived air concentrations (DACS). These limits are the total amounts allowed if no external radiation is received. The resulting dose from the internal radiation sources (from breathing air at 1 DAC) is the maximum allowed to an organ or to the worker's whole -body.

6. <u>How does radiation cause cancer?</u>

The mechanisms of radiation-induced cancer are not completely understood. When radiation interacts with the cells of our bodies, a number of events can occur. The damaged cells can repair themselves and permanent damage is not caused. The cells can die, much like the large numbers of cells that die every day in our bodies and be replaced through the normal biological processes. Or a change can occur in the cell's reproductive structure, the cells can mutate and subsequently be repaired without effect, or they can form precancerous cells, which may become cancerous. Radiation is only one of many agents with the potential for causing cancer, and cancer caused by radiation cannot be distinguished from cancer attributable to any other cause. Radiobiologists have studied the relationship between large doses of radiation and cancer. These studies indicate that damage or change to genes in the cell nucleus is the main cause of radiation-induced cancer. This damage may occur directly through the interaction of the ionizing radiation in the cell or indirectly through the actions of chemical products produced by radiation interactions within cells. Cells are able to repair most damage within hours; however, some cells may not be repaired properly. Such misrepaired damage is thought to be the origin of cancer, but misrepair does not always cause cancer. Some cell changes are benign or the cell may die; these changes do not lead to cancer. Many factors such as age, general health, inherited traits, sex, as well as exposure to other cancer-causing agents such as cigarette smoke can affect susceptibility to the cancer-causing effects of radiation. Many diseases are caused by the interaction of several factors, and these interactions appear to increase the susceptibility to cancer.

7. Who developed radiation risk estimates?

Radiation risk estimates were developed by several national and international scientific organizations over the last 40 years. These organizations include the National Academy of Sciences (which has issued several reports from the Committee on the Biological Effects of Ionizing Radiations, BEIR), the National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Each of these organizations continues to review new research findings on radiation health risks. Several reports from these organizations present new findings on radiation risks based upon revised estimates of radiation dose to survivors of the atomic bombing at Hiroshima and Nagasaki. For example, UNSCEAR published risk estimates in 1988 and 1993. The NCRP also published a report in 1988, "New Dosimetry at Hiroshima and Nagasaki and Its Implications for Risk Estimates." In January 1990, the National Academy of Sciences released the fifth report of the BEIR Committee, "Health Effects of Exposure to Low Levels of Ionizing Radiation." Each of these publications also provides extensive bibliographies on other published studies concerning radiation health effects for those who may wish to read further on this subject.

8. What are the estimates of the risk of fatal cancer from radiation exposure?

We don't know exactly what the chances are of getting cancer from a low-level radiation dose, primarily because the few effects that may occur cannot be distinguished from normally occurring cancers. However, we can make estimates based on extrapolation from extensive knowledge from scientific research on high dose effects. The estimates of radiation effects at high doses are better known than are those of most chemical carcinogens. From currently available data, the NRC has adopted a risk value for an occupational dose of 1 rem (0.01 Sv) Total Effective Dose Equivalent (TEDE) of 4 in 10,000 of developing a fatal cancer, or approximately 1 chance in 2,500 of fatal cancer per rem of TEDE received. The uncertainty associated with this risk estimate does not rule out the possibility of higher risk, or the possibility that the risk may even be zero at low occupational doses and dose rates. The radiation risk incurred by a worker depends on the amount of dose received. Under the linear model explained above, a worker who receives 5 rems (0.05 Sv) in a year incurs 10 times as much risk as another worker who receives only 0.5 rem (0.005 Sv). Only a very few workers receive doses near 5 rems (0.05 Sv) per year. According to the BEIR V report (Ref. 4), approximately one in five adults normally will die from cancer from all possible causes such as smoking, food, alcohol, drugs, air pollutants, natural background radiation, and inherited traits. Thus, in any group of 10,000 workers, we can estimate that about 2,000 (20%) will die from cancer without any occupational radiation exposure. To explain the significance of these estimates, we will use as an example a group of 10,000 people, each exposed to 1 rem (0.01 Sv) of ionizing radiation. Using the risk factor of 4 effects per 10,000 rem of

dose, we estimate that 4 of the 10,000 people might die from delayed cancer because of that l-rem dose (although the actual number could be more or less than 4) in addition to the 2,000 normal cancer fatalities expected to occur in that group from all other causes. This means that a l-rem (0.01 Sv) dose may increase an individual worker's chances of dying from cancer from 20 percent to 20.04 percent. If one's lifetime occupational dose is 10 rems, we could raise the estimate to 20.4 percent. A lifetime dose of 100 rems may increase chances of dying from cancer from 20 to 24 percent. The average measurable dose for radiation workers reported to the NRC was 0.31 rem (0.0031 Sv) for 1993. Today, very few workers ever accumulate 100 rems (1 Sv) in a working lifetime, and the average career dose of workers at NRC-licensed facilities is 1.5 rems (0.015 Sv), which represents an estimated increase from 20 to about 20.06 percent in the risk of dying from cancer. It is important to understand the probability factors here. A similar question would be, "If you select one card from a full deck of cards, will you get the ace of spades?" This question cannot be answered with a simple yes or no. The best answer is that your chance is 1 in 52. However, if 1000 people each select one card from full decks, we can predict that about 20 of them will get an ace of spades, each person will have 1 chance in 52 of drawing the ace of spades, but there is no way we can predict which persons will get that card.
The issue is further complicated by the fact that in a drawing by 1000 people, we might get only 15 successes, and in another, perhaps 25 correct cards in 1000 draws. We can say that if you receive a radiation dose, you will have increased your chances of eventually developing cancer. It is assumed that the more radiation exposure you get, the more you increase your chances of cancer. The normal chance of dying from cancer is about one in five for persons who have not received any occupational radiation dose. The additional chance of developing fatal cancer from an occupational exposure of 1 rem (0.01 Sv) is about the same as the chance of drawing any ace from a full deck of cards three times in a row. The additional chance of dying from cancer from an occupational exposure of 10 rem (0.01 Sv) is about equal to your chance of drawing two aces successively on the first two draws from a full deck of cards. It is important to realize that these risk numbers are only estimates based on data for people and research animals exposed to high levels of radiation in short periods of time. There is still uncertainty with regard to estimates of radiation risk from low levels of exposure. Many difficulties are involved in designing research studies that can accurately measure the projected small increases in cancer cases that might be caused by low exposures to radiation as compared to the normal rate of cancer. These estimates are considered by the NRC staff to be the best available for the worker to use to make an informed decision concerning acceptance of the risks associated with exposure to radiation. A worker who decides to accept this risk should try to keep exposure to radiation as low as is reasonably achievable (ALARA) to avoid unnecessary risk.

9. <u>If I receive a radiation dose that is within occupational limits, will it cause me to get cancer?</u>

Probably not. Based on the risk estimates previously discussed, the risk of cancer from doses below the occupational limits is believed to be small, Assessment of the cancer risks that may be associated with low doses of radiation are projected from data avail-able at doses larger than 10 rems (0.1 Sv). For radiation protection purposes, these estimates are made using the straight-line portion of the linear quadratic model. We have data on cancer probabilities only for high doses. Only in studies involving radiation doses above occupational limits are there dependable determinations of the risk of cancer, primarily because below the limits the effect is small compared to differences in the normal cancer incidence from year to year and place to place. The ICRP, NCRP, and other standards-setting organizations assume for radiation protection purposes that there is some risk, no matter how small the dose. Some scientists believe that the risk drops off to zero at some low dose, the threshold effect, The ICRP and NCRP endorse the linear quadratic model as a conservative means of assuring safety. For regulatory purposes, the NRC uses the linear model, which shows the number of effects decreasing linearly as the dose decreases. Because the scientific evidence does not conclusively demonstrate whether there is or is not an effect at low doses, the NRC assumes for radiation protection purposes, that even small doses have some chance of causing cancer. Thus, a principle of radiation protection is to do more than merely meet the allowed regulatory limits; doses should be kept as low as is reasonably achievable (ALARA). This is as true for natural carcinogens such as sunlight and natural radiation as it is for those that are manmade, such as cigarette smoke, smog, and x-rays.

10. <u>How can we compare the risk of cancer from radiation to other kinds of health risks?</u>

One way to make these comparisons is to compare the average number of days of life expectancy lost because of the effects associated with each particular health risk. Estimates are calculated by looking at a large number of persons, recording the age when death occurs from specific causes, and estimating the average number of days of life lost as a result of these early deaths. The total number of days of life lost is then averaged over the total observed group. Several studies have compared the average days of life lost from exposure to radiation with the number of days lost as a result of being exposed to other health risks. The word “average” is important because an individual who gets cancer loses about 15 years of life expectancy, while his or her coworkers do not suffer any loss. Some representative numbers are presented in Table 1. For categories of NRC-regulated industries with larger doses, the average measurable occupational dose in 1993 was 0.31 rem (0.0031 Sv). A simple calculation based on the article by Cohen and Lee shows that 0.3 rem (0.003 Sv) per year from age 18 to 65 results in an average loss of 15 days. These estimates indicate that the health risks from occupational radiation exposure are smaller than the risks associated with many other events or activities we encounter and accept in normal day-to-day activities. It is also useful to compare the estimated average number of days of life lost from occupational exposure to radiation with the number of days lost as a result of average days of life expectancy lost as a result of fatal work-related accidents. Table 2 does not include non-accident types of occupational risks such as occupational disease and stress because the data are not available. These comparisons are not ideal because we are comparing the possible effects of chronic exposure to radiation to different kinds of risk such as accidental death, in which death is inevitable if the event occurs. This is the best we can do because good data are not available on chronic exposure to other workplace carcinogens. Also, the estimates of loss of life expectancy for workers from radiation-induced cancer do not take into consideration the competing effect on the life expectancy of the workers from industrial accidents.

<u>Table 1 Estimated Loss of Life Expectancy from Health Risks</u>

HEALTH RISK	ESTIMATE OF LIFE EXPECTANCY LOST
Smoking 20 cigarettes a day	6 years
15% Overweight	2 years
US Average alcohol consumption	1 year
All accidents combined	1 year
Motor vehicle accidents	207 days
Home accidents	74 days
Drowning	24 days
Natural hazards (earthquake, lightning, flood, etc.)	7 days
Medical radiation exposure	6 days
Occupational radiation exposure 0.3 rem/yr age 18 to 65	15 days
Occupational radiation exposure 1.0 rem/yr age 18 to 65	51 days

<u>Table 2 Estimated Loss of Life Expectancy from Industrial Accidents</u>

INDUSTRY TYPE	ESTIMATED DAYS OF LIFE EXPECTANCY LOST
All industries	60
Agriculture	320
Construction	227
Mining and quarrying	167
Transportation and public utilities	160
Government	60
Manufacturing	40
Trade	27

Services	27

11. What are the health risks from radiation exposure to the embryo/fetus?

During certain stages of development, the embryo/fetus is believed to be more sensitive to radiation damage than adults. Studies of atomic bomb survivors exposed to acute radiation doses exceeding 20 rads (0.2 Gy) during pregnancy show that children born after receiving these doses have a higher risk of mental retardation. Other studies suggest that an association exists between exposure to diagnostic x-rays before birth and carcinogenic effects in childhood and in adult life. Scientists are uncertain about the magnitude of the risk. Some studies show the embryo/fetus to be more sensitive to radiation-induced cancer than adults, but other studies do not. In recognition of the possibility of increased radiation sensitivity, and because dose to the embryo/fetus is involuntary on the part of the embryo/fetus, a more restrictive dose limit has been established for the embryo/fetus of a declared pregnant radiation worker. See Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure." If an occupationally exposed woman declares her pregnancy in writing, she is subject to the more restrictive dose limits for the embryo/fetus during the remainder of the pregnancy. The dose limit of 500 mrems (5 mSv) for the total gestation period applies to the embryo/fetus and is controlled by restricting the exposure to the declared pregnant woman. Restricting the woman's occupational exposure, if she declares her pregnancy, raises questions about individual privacy rights, equal employment opportunities, and the possible loss of income. Because of these concerns, the declaration of pregnancy by a female radiation worker is voluntary. Also, the declaration of pregnancy can be withdrawn for any reason, for example, if the woman believes that her benefits from receiving the occupational exposure would outweigh the risk to her embryo/fetus from the radiation exposure.

12. Can a worker become sterile or impotent from normal occupational radiation exposure?

No. Temporary or permanent sterility cannot be caused by radiation at the levels allowed under NRC's occupational limits. There is a threshold below which these effects do not occur. Acute doses on the order of 10 rems (0.1 Sv) to the testes can result in a measurable but temporary reduction in sperm count. Temporary sterility (suppression of ovulation) has been observed in women who have received acute doses of 150 rads (1.5 Gy). The estimated threshold (acute) radiation dose for induction of permanent sterility is about 200 rads (2 Gy) for men and about 350 rads (3.5 Gy) for women. These doses are far greater than the NRC s occupational dose limits for workers. Although acute doses can affect fertility by reducing sperm count or suppressing ovulation, they do not have any direct effect on one's ability to function sexually. No evidence exists to suggest that exposures within the NRC's occupational limits have any effect on the ability to function sexually.

13. What are the NRC occupational dose limits?

For adults, an annual limit that does not exceed:
5 rems (0.05 Sv) for the total effective dose equivalent (TEDE), which is the sum of the deep dose equivalent (DDE) from external exposure to the whole body and the committed effective dose equivalent (CEDE) from intakes of radioactive material. 50 rems (0.5 Sv) for the total organ dose equivalent (TODE), which is the sum of the DDE from external exposure to the whole body and the committed dose equivalent (CDE) from intakes of radioactive material to any individual organ or tissue, other than the lens of the eye. 15 rems (0.15 Sv) for the lens dose equivalent (LDE), which is the external dose to the lens of the eye. 50 rems (0.5 Sv) for the shallow dose equivalent (SDE), which is the external dose to the skin or to any extremity.

For minor workers, the annual occupational dose limits are 10 percent of the dose limits for adult workers.

For protection of the embryo/fetus of a declared pregnant woman, the dose limit is 0.5 rem (5 mSv) during the entire pregnancy.

The occupational dose limit for adult workers of 5 rems (0.05 Sv) TEDE is based on consideration of the potential for delayed biological effects. The 5 rem (0.05 Sv) limit, together with application of the concept of keeping occupational doses ALARA, provides a level of risk of delayed effects considered acceptable by the NRC. The limits for individual organs are below the dose levels at which early biological effects are observed in the individual organs. The dose limit for the embryo/fetus of a declared pregnant woman is based on a consideration of the possibility of greater sensitivity to radiation of the embryo/fetus and the involuntary nature of the exposure.

14. What is meant by ALARA?

ALARA means "as low as is reasonably achievable." In addition to providing an upper limit on an individual's permissible radiation dose, the NRC requires that its licensees establish radiation protection programs and use procedures and engineering controls to achieve occupational doses, and doses to the public, as far below the limits as is reasonably achievable. "Reasonably achievable" also means "to the extent practicable." What is practicable depends on the purpose of the job, the state of technology, the costs for averting doses, and the benefits. Although implementation of the ALARA principle is a required integral part of each licensee's radiation protection program, it does not mean that each radiation exposure must be kept to an absolute minimum, but rather that "reasonable" efforts must be made to avert dose. In practice, ALARA includes planning tasks involving radiation exposure so as to reduce dose to individual workers and the work group. There are several ways to control radiation doses, e .g, limiting the time in radiation areas, maintaining distance from sources of radiation, and providing shielding of radiation sources to reduce dose. The use of engineering controls, from the design of facilities and equipment to the actual set-up and conduct of work activities, is also an important element of the ALARA concept. An ALARA analysis should be used in determining whether the use of respiratory protection is advisable. In evaluating whether or not to use respirators, the goal should be to achieve the optimal sum of external and internal doses. For example, the use of respirators can lead to increased work time within radiation areas, which increases external dose. The advantage of using respirators to reduce internal exposure must be evaluated against the increased external exposure and related stresses caused by the use of respirators. Heat stress, reduced visibility, and reduced communication associated with the use of respirators could expose a worker to far greater risks than are associated with the internal dose avoided by use of the respirator. To the extent practical, engineering controls, such as containment and ventilation systems, should be used to reduce workplace airborne radioactive materials.

15. What are background radiation exposures?

The average person is constantly exposed to ionizing radiation from several sources. Our environment and even the human body contain naturally occurring radioactive materials (e.g., potassium-40) that contribute to the radiation dose that we receive. The largest source of natural background radiation exposure is terrestrial radon, a colorless, odorless, chemically inert gas, which causes about 55 percent of our average, non-occupational exposure. Cosmic radiation originating in space contributes additional exposure. The use of x-rays and radioactive materials in medicine and dentistry adds to our population exposure. As shown below in Table 3, the average person receives an annual radiation dose of about 0.36 rem (3.6 mSv). By age 20, the average person will accumulate over 7 rems (70 mSv) of dose. By age 50, the total dose is up to 18 rems (180 mSv). After 70 years of exposure this dose is up to 25 rem (250 mSv).

Table 3 Average Annual Effective Dose Equivalent to Individuals in the U. S.

SOURCE	EFFECTIVE DOSE EQUIVALENT (MREMS)
Natural radon	200

Other radon total	300
Nuclear fuel cycle	0.05
Consumer products	9
Diagnostic x-rays	39
Nuclear medicine	53
US Average Annual Total	360

16. What are the typical radiation doses received by workers?

For 1993, the NRC received reports on about a quarter of a million people who were monitored for occupational exposure to radiation. Almost half of those monitored had no measurable doses. The other half had an average dose of about 310 mrem (3.1 mSv) for the year. Of these, 93 percent received an annual dose of less than 1 rem (10 mSv); 98.7 percent received less than 2 rems (20 mSv); and the highest reported dose was for two individuals who each received between 5 and 6 rems (50 and 60 mSv). Table 4 lists average occupational doses for workers (persons who had measurable doses) in various occupations based on 1993 data. It is important to note that beginning in 1994, licensees have been required to sum external and internal doses and certain licensees are required to submit annual reports. Certain types of licensees such as nuclear fuel fabricators may report a significant increase in worker doses because of the exposure to long-lived airborne radionuclides and the requirement to add the resultant internal dose to the calculation of occupational doses.

Table 4 Reported Occupational Doses for 1993

OCCUPATIONAL SUBGROUP	AVERAGE MEASURABLE DOSE PER WORKER (MREMS)
Industrial radiography	540
Commercial nuclear power reactors	310
Manufacturing and distribution of radioactive material	300
Low-level radioactive waste disposal	270
Independent spent nuclear fuel storage	260
Nuclear fuel fabrication	130

17. How do I know how much my occupational dose (exposure) is?

If you are likely to receive more than 10 percent of the annual dose limits, the NRC requires your employer, the NRC licensee, to monitor your dose, to maintain records of your dose, and, at least on an annual basis for the types of licensees listed in 10 CFR 20.2206, “Reports of Individual Monitoring,” to inform both you and the NRC of your dose. The purpose of this monitoring and reporting is so that the NRC can be sure that licensees are complying with the occupational dose limits and the ALARA principle. External exposures are monitored by using individual monitoring devices. These devices are required to be used if it appears likely that external exposure will exceed 10 percent of the allowed annual dose, i.e., 0.5 rem (5 mSv). The most commonly used monitoring devices are film badges, thermoluminescence dosimeters (TLDs), electronic dosimeters, and direct reading pocket dosimeters. With respect to internal exposure, your employer is required to monitor your occupational intake of radioactive material and assess the resulting dose if it appears likely that you will receive greater than 10 percent of the annual limit on intake (ALI) from intakes in 1 year. Internal exposure can be estimated by measuring the radiation emitted from the body (for example, with a “whole body counter”) or by measuring the radioactive materials contained in biological samples such as urine or feces. Dose estimates can also be made if one knows how much radioactive material was in the air and the length of time during which the air was breathed.

18. What happens if a worker exceeds the annual dose limit?

If a worker receives a dose in excess of any of the annual dose limits, the regulations prohibit any occupational exposure during the remainder of the year in which the limit is exceeded. The licensee is also required to file an overexposure report with the NRC and provide a copy to the individual who received the dose. The licensee may be subject to NRC enforcement action such as a fine (civil penalty), just as individuals are subject to a traffic fine for exceeding a speed limit. The fines and, in some serious or repetitive cases, suspension of a license are intended to encourage licensees to comply with the regulations. Radiation protection limits do not define safe or unsafe levels of radiation exposure. Exceeding a limit does not mean that you will get cancer. For radiation protection purposes, it is assumed that risks are related to the size of the radiation dose. Therefore, when your dose is higher your risk is also considered to be higher. These limits are similar to highway speed limits. If you drive at 70 mph, your risk is higher than at 55 mph, even though you may not actually have an accident. Those who set speed limits have determined that the risks of driving in excess of the speed limit are not acceptable. In the same way, the revised 10 CFR Part 20 establishes a limit for normal occupational exposure of 5 rems (0.05 Sv) a year. Although you will not necessarily get cancer or some other radiation effect at doses above the limit, it does mean that the licensee's safety program has failed in some way, Investigation is war-ranted to determine the cause and correct the conditions leading to the dose in excess of the limit.

19. <u>What is meant by a "planned special exposure?"</u>

A "planned special exposure" (PSE) is an infrequent exposure to radiation, separate from and in addition to the radiation received under the annual occupational limits. The licensee can authorize additional dose in any one year that is equal to the annual occupational dose limit as long as the individual's total dose from PSEs does not exceed five times the annual dose limit during the individual's lifetime. For example, licensees may authorize PSEs for an adult radiation worker to receive doses up to an additional 5 rems (0.05 Sv) in a year above the 5 rem (0.05-Sv) annual TEDE occupational dose limit. Each worker is limited to no more than 25 rems (0.25 Sv) from planned special exposures in his or her lifetime. Such exposures are only allowed in exceptional situations when alternatives for avoiding the additional exposure are not available or are impractical. Before the licensee authorizes a PSE, the licensee must ensure that the worker is informed of the purpose and circumstances of the planned operation, the estimated doses expected, and the procedures to keen the doses ALARA while considering other risks that may be present. (See Regulatory Guide 8.35, "Planned Special Exposures.")

20. <u>Why do some facilities establish administrative control levels that are below the NRC limits?</u>

There are two reasons. First, the NRC regulations state that licensees must take steps to keep exposures to radiation ALARA. Specific approval from the licensee for workers to receive doses in excess of administrative limits usually results in more critical risk-benefit analyses as each additional increment of dose is approved for a worker. Secondly, an administrative control level that is set lower than the NRC limit provides a safety margin designed to help the licensee avoid doses to workers in excess of the limit.

21. <u>Why aren't medical exposures considered as part of a worker's allowed dose?</u>

NRC rules exempt medical exposure, but equal doses of medical and occupational radiation have equal risks. Medical exposure to radiation is justified for reasons that are quite different from the reasons for occupational exposure. A physician prescribing an x-ray, for example, makes a medical judgment that the benefit to the patient from the resulting medical information justifies the risk associated with the radiation. This judgment may or may not be accepted by the patient. Similarly, each worker must decide on the benefits and acceptability of occupational radiation risk, just as each worker must decide on the acceptability of any other occupational hazard. Consider a worker who receives a dose of 3 rems (0.03 Sv) from a series of x-rays in connection with an injury or illness. This dose and any associated risk must be justified on medical grounds. If the worker had also received 2 rems (0.02 Sv) on the job, the combined dose of 5 rems (0.05 Sv) would in no way incapacitate the worker. Restricting the worker from additional job exposure during the remainder of the year would not have any effect on the risk from the 3 rems (0.03 Sv) already received from the medical exposure. If the individual worker accepts the risks associated with the x-rays on the basis of the medical benefits and accepts the risks associated with job-related exposure on the basis of employment benefits, it would be unreasonable to restrict the worker from employment involving exposure to radiation for the remainder of the year.

22. How should radiation risks be considered in an emergency?

Emergencies are “unplanned” events in which actions to save lives or property may warrant additional doses for which no particular limit applies. The revised 10 CFR Part 20 does not set any dose limits for emergency or lifesaving activities and states that nothing in Part 20 “shall be construed as limiting actions that may be necessary to protect health and safety.” Rare situations may occur in which a dose in excess of occupational limits would be unavoidable in order to carry out a lifesaving operation or to avoid a large dose to large populations. However, persons called upon to undertake any emergency operation should do so only on a voluntary basis and with full awareness of the risks involved. For perspective, the Environmental Protection
Agency (EPA) has published emergency dose guidelines. These guidelines state that doses to all workers during emergencies should, to the extent practicable, be limited to 5 rems (0.05 Sv). The EPA further states that there are some emergency situations for which higher limits may be justified. The dose resulting from such emergency exposures should be limited to 10 rems (0.1 Sv) for protecting valuable property, and to 25 rems (0.25 Sv) for lifesaving activities and the protection of large populations. In the context of this guidance, the dose to workers that is incurred for the protection of large populations might be considered justified for situations in which the collective dose to others that is avoided as a result of the emergency operation is significantly larger than that incurred by the workers involved. Table 5 presents the estimates of the fatal cancer risk for a group of 1,000 workers of various ages, assuming that each worker received an acute dose of 25 rems (0.25 Sv) in the course of assisting in an emergency. The estimates show that a 25-rem emergency dose might increase an individual’s chances of developing fatal cancer from about 20% to about 2170.

Table 5: Risk of Premature Death from Exposure to 25-Rems (0.25-Sv) Acute Dose

AGE AT EXPOSURE (YEARS)	ESTIMATED RISK OF PREMATURE DEATH (PER 1000 INDIVIDUALS)
20-30	9.1
30-40	7.2
40-50	5.3
50-60	3.5

23. How were radiation dose limits established?

The NRC radiation dose limits in 10 CFR Part 20 were established by the NRC based on the recommendations of the ICRP and NCRP as endorsed in Federal radiation protection guidance developed by the EPA. The limits were recommended by the ICRP and NCRP with the objective of ensuring that working in a radiation-related industry was as safe as working in other comparable industries. The dose limits and the principle of ALARA should ensure that risks to workers are maintained indistinguishable from risks from background radiation.

24. Several scientific reports have recommended that the NRC establish lower dose limits. Does the NRC plan to reduce the regulatory limits?

Since publication of the NRC’s proposed rule in 1986, the ICRP in 1990 revised its recommendations for radiation protection based on newer studies of radiation risks, and the NCRP followed with a revision to its recommendations in 1993. The ICRP recommended a limit of 10 rems (0.1 Sv) effective dose equivalent (from internal and external sources), over a 5-year period with no more than 5 rems (0.05 Sv) in 1 year. The NCRP recommended a cumulative limit in rems, not to exceed the individual's age in years, with no more than 5 rems (0.05 Sv) in any year. The NRC does not believe that additional reductions in the dose limits are required at this time. Because of the practice of maintaining radiation exposures ALARA (as low as is reasonably achievable), the average radiation dose to occupationally exposed persons is well below the limits in the current Part 20 that became mandatory January 1, 1994, and the average doses to radiation workers are below the new limits recommended by the ICRP and the NCRP.

25. <u>What are the options if a worker decides that the risks associated with occupational radiation exposure are too high?</u>

If the risks from exposure to occupational radiation are unacceptable to a worker, he or she can request a transfer to a job that does not involve exposure to radiation. However, the risks associated with the exposure to radiation that workers, on the average, actually receive are comparable to risks in other industries and are considered acceptable by the scientific groups that have studied them. An employer is not obligated to guarantee a transfer if a worker decides not to accept an assignment that requires exposure to radiation. Any worker has the option of seeking other employment in a non-radiation occupation. However, the studies that have compared occupational risks in the nuclear industry to those in other job areas indicate that nuclear work is relatively safe. Thus, a worker may find different kinds of risk but will not necessarily find significantly lower risks in another job.

26. <u>Where can one get additional information on radiation risk?</u>

The following list suggests sources of useful information on radiation risk:

Nuclear Regulatory Commission Regional Offices:
King of Prussia, Pennsylvania (610) 337-5000
Atlanta, Georgia (404) 331-4503
Lisle, Illinois (708) 829-9500
Arlington, Texas (817) 860-8100

U.S. Nuclear Regulatory Commission Headquarters Radiation Protection & Health Effects Branch

Office of Nuclear Regulatory Research
Washington, DC 20555
Telephone: (301) 415-6187

Department of Health and Human Services
Center for Devices and Radiological Health
1390 Piccard Drive, MS HFZ-1
Rockville, MD 20850
Telephone: (301) 443-4690

U. S. Environmental Protection Agency
Office of Radiation and Indoor Air
Criteria and Standards Division
401 M Street NW.
Washington, DC 20460
Telephone: (202) 233-9290

APPENDIX R

Transportation of Radioactive Material

Requirements for the transportation of radioactive material on campus and to other institutions must comply with both the NRC and DOT regulations. Transporting may involve walking or driving radioactive material across campus or shipping off campus. The OEHS must be notified before any transfers take place. This is to ensure that proper procedures are followed and movement of radioactive material is tracked. Any transfers of radioactive material (possession transferred from one principal investigator to another) must be pre-authorized by the OEHS.

Package Preparation

All packages used to transport radioactive material must be strong, tight containers that will not leak under normal transportation conditions (such as dropping, jarring or temperature extremes).
If liquid is shipped, use at least twice the amount of absorbent needed to contain the entire volume in case the container should break or leak. If you are not sure whether the container you plan to use is adequate, contact the OEHS.

Transportation on Campus

Whenever radioactive material is transported from one building to another, the OEHS must be notified of the following information:

Complete the form on OEHS website under the Radiation Safety Tab:

- When the material will need to be moved
- The names of the person sending and receiving the material (if different)
- The sending and receiving locations
- The nuclide(s) being moved
- The chemical form of the isotope
- The total activity in mCi
- Number of containers
- Phone numbers of responsible persons
- Any special conditions

<u>Walking to another building You must complete the online form.</u>

Prepare to move your material using an appropriate container (see Package Preparation above).
The package must have a radioactive warning label with the isotope, activity in DPM, uCi or mCi and date. Clearly identify the principal investigator and one other contact in case of an accident or loss of the package. The package must be tested for removable contamination before it leaves its place of origin and after it reaches it destination. Contact the OEHS if any removable contamination is detected.

<u>Driving to another building</u>

The transportation of radioactive material is regulated by the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT). **You must not move any radioactive material on a public road without prior authorization by the OEHS. You must complete the online form**

Remember that all roads on the WSU campus are public. The OEHS will prepare documentation and transport your material. The sender's responsibility is to contact the OEHS in advance, and properly package the radioactive material. If driving you will need to have training in both Hazardous Materials and DOT.

Prepare to move your material using an appropriate container (see Package Preparation above). The OEHS will determine what package labeling is required. Do not seal the package. The condition of the package must be checked and a leak test performed by the OEHS. A radiation worker must be present at the receiving location to take possession of the material at the arranged time.

Shipping Radioactive Material (off campus)

When preparing to ship radioactive material, whether it is radioactive samples or a piece of equipment being returned for repairs, the OEHS must be informed in advance. **Do not expect to send shipments out immediatel**y. Federal regulations must be followed regardless of the quantity being sent.

Shipments can only be made to institutions that are licensed to possess radioactive material. When shipping to another licensee, prior authorization from the Radiation Safety Office at that location is required. License information must be on record or obtained before the shipment can be sent. To initiate this process, the person sending the material must have the following information:

- The name of the person sending the material
- Facility name and address
- The name of the person receiving the material
- The Radiation Safety Officer's (or other staff member) name and phone number
- The nuclide(s) being sent
- The chemical form of each isotope
- The total activity in mCi for each isotope
- Number of containers in the shipment
- Any special conditions.

Prepare to ship your material using an appropriate container (see Package Preparation above). The OEHS will determine what package labeling is required. Do not seal the package, as the condition of the package must be checked and a leak test performed by the OEHS. Labels will be placed on the package, if required. When the package and paperwork are in order, the OEHS will transport the package to the U.S. Postal Office. Copies of the shipping papers, material return form, and any other paperwork will be made and maintained for review at the OEHS.

Remember that shipments of radioactive material must be planned well in advance; allow at least two weeks prior to the desired shipping date.

Appendix S

Radioactive Material Decay-In-Storage and Disposal Record Record

Emergency Contact Radiation Safety Officer: Maha Srinivasan (313) 577-0019
Radiation Safety Staff (313) 577-1200

Before disposal as ordinary trash, byproduct material must be surveyed at the container surface with the appropriate survey meter set on its most sensitive scale and with no interposed shielding to determine that its radioactivity cannot be distinguished from background. All radiation labels must be obliterated. A record of each disposal must be retained for a minimum of 3 years.

Lab location Room & Building	Isotope	Date put in hold for decay	Date disposed	mR/hr background	mR/hr surface of waste (at contact) at disposal	Instrument used SN number & calibration date	Name of person performing disposal

APPENDIX T

References and Other Resources

SELECTED BIBLIOGRAPHY

(and additional sources of information)

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Cobb, Charles E., Jr., and Karen Kasmauki. 1989. Living With Radiation. National Geographic, 175: 402 (36).

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Miller, Kenneth L. 1992. CRC Handbook of Management of Radiation Protection Programs. Boca Raton, FL. CRC Press, Inc.

Moeller, Dade. 1992. Environmental Health. Cambridge, MA: Harvard University Press.

Shleien, Bernard, ed. 1992. The Health Physics and Radiological Health Handbook. Silver Spring, MD: Scinta Inc.

Shapiro, Jacob. 1990. Radiation Protection. Cambridge, MA: Harvard University Press.

Yalow, Rosalyn S. 1994. Concerns with Low-level Ionizing Radiation. Mayo Clinic Proceedings, 69: 436-440.

Fundamentals of Radiological Protection. 1993. Radiation Safety Associates Publications, 19 Pendleton Drive, P.O. Box 19, Hebron, CT 06248. (203) 228-0824

Radiological Health Handbook. 1970. Compiled and edited by the Bureau of Radiological Health and The Training Institute, Environmental Control Administration. Washington, D. C.: Government Printing Office.

Chart of the Nuclides. 14th edition. Available as wall chart (50" x 29") or booklet (8 1/2" x 11") from: GE Nuclear Energy, General Electric Company, Nuclear Energy Operations, 175 Curtner Ave, M/C 397, San Jose, CA 95125. Cost: approx. $12.

The Medical Internal Radiation Dose Committee (MIRD) of the Society of Nuclear Medicine publishes a series of pamphlets giving methods and data for absorbed dose calculations. The pamphlets may be purchased from MIRD Committee, 404 Church Ave., Suite 15, Maryville, TN 37801.

The National Council on Radiation Protection and Measurements (NCRP) issues reports providing information and recommendations based on leading scientific judgment on matters of radiation protection and measurement. Reports are available from NCRP Publications, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

The International Commission on Radiation Units and Measurements (ICRU) issues reports concerned with the definition, measurement, and application of radiation quantities in clinical radiology and radiobiology.
Reports are available from ICRU, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

The International Commission on Radiological Protection (ICRP) issues reports dealing with the basic principles of radiation protection. The reports may be obtained from Pergamon Press, Maxwell House, Fairview Part, Elmsford, NY 10523.
The International Atomic Energy Agency issues many publications pertaining to the nuclear science field, including the proceedings of symposia, a Safety Series covering topics in radiation protection, a Technical Reports Series, a Bibliographical Series, and a Review Series. A complete catalog of publications may be obtained from the Publishing Section, International Atomic Energy Agency, Karnter Ring 11, P. O. Box 590, A-1011 Vienna, Austria. Publications may be ordered from UNIPUB, Inc., P. O. Box 433, New York, NY 10016.

National Consensus Standards relating to radiation protection provide information and guidance and are often incorporated into the regulations of the Nuclear Regulatory Commission. The major national organization issuing such standards is the American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018.

The U. S. Nuclear Regulatory Commission issues guides that describe methods acceptable to the NRC staff for implementing specific parts of the Commission's regulations. Request information from the U. S. Nuclear Regulatory Commission, Washington, D. C. 20555, Attention: Director, Office of Nuclear Regulatory Research.

Health Physics, the official journal of the Health Physics Society, is a valuable source of information in radiation protection.

Health Physics Society Newsletter, a publication of the Health Physics Society, 8000 Westpark Dr., Ste 130, McLean, VA 22102.

Radiation Protection Management: The Journal of Applied Health Physics. RSA Publications, 19 Pendleton Drive, P. O. Box 19, Hebron, CT 06248.

OTHER REFERENCE RESOURCES

Excellent resources are available on the computer internet. Several are listed below.
Wayne State University OEHS http:www.oehs.wayne.edu:
Michigan State University OCRBS:http://www.orcbs.msu.edu
RADSAFE: A list server for radiation safety. To subscribe, send an email request to: romulus.ehs.usuc.edu
SAFETY: A world wide list service for general safety. To subscribe, send email request to uvmvm.uvm.edu
Radiation and Health Physics Home Page: http://www.umich.edu/~bbusby/
University of Michigan Radiation Safety Home Page: http://www.umich.edu/~oseh/rss.html
DOE Office of Human Radiation Experiments Home Page: http://www.eh.doe.gov/ohre/home.htm
U.S. Nuclear Regulatory Commission Home Page: http://www.nrc.gov/
Health Physics Society Home Page: http://www.hps.org/hps
Safety Mother Lode (Comprehensive safety listings): http://www.sas.ab.ca/biz/christie/safelist.html#web

Radiation and Us:
http://www.einet.net/galaxy/Community/Health/Environmental-Health/bruce-busby/rad.htm

Radiation Biology Home Page: http://www.science.ubc.ca/departments/physics/radbio/HomePage.html

Glossary

Absorbed Dose
The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the rad, which is 100 ergs/gram.

Absorption
The phenomenon by which radiation imparts some or all of its energy to any material through which it passes.

Activation
The process of making a material radioactive by bombardment with neutrons, protons, or other form of ionizing radiation.

Activity
The number of nuclear disintegration occurring in a given quantity of material per unit time.

Acute Exposure
The absorption of a relatively large amount of radiation (or intake of radioactive material) over a short period of time.

Acute Health Effects
Prompt radiation effects (those that would be observable within a short period of time) for which the severity of the effect varies with the dose, and for which a practical threshold exists.

Adult
An individual 18 or more years of age.

ALARA
Acronym for As Low As Reasonably Achievable; making every reasonable effort to maintain exposures to
radiation as far below the dose limits as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Alpha Particle
A strongly ionizing particle emitted from the nucleus during radioactive decay having a mass and charge equal in magnitude to a helium nucleus, consisting of 2 protons and 2 neutrons with a double positive charge.

Alpha Ray
A stream of fast-moving helium nuclei (alpha particles), a strongly ionizing and weakly penetrating radiation.

Anion
A negatively charged ion.

Annual Limit of Intake (ALI)
The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the

reference man that would result in a committed effective dose equivalent of 5 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue.

Atom
Smallest particle of an element which is capable of entering into a chemical reaction.

Attenuation
The process by which a beam of radiation is reduced in intensity when passing through some material. It is
the combination of absorption and scattering processes and leads to a decrease in flux density of the beam
when projected through matter.

Background Radiation
Ionizing radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

Becquerel
The international (SI) the unit for radioactivity in which the number of disintegration is equal to one disintegration per second. A charged particle emitted from the nucleus of an atom during radioactive decay.

Beta Particle
Charged particle emitted from the nucleus of an atom during radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

Beta Ray
A stream of high-speed electrons or positrons of nuclear origin more penetrating, but less ionizing than alpha rays.

Bioassay
The determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Body Burden
The amount of radioactive material which if deposited in the total body will produce the maximum permissible dose rate to the critical organ.

Bremsstrahlung
Electromagnetic (x-ray) radiation produced by the deposition of charged particles in matter. Secondary photon radiation (x-ray) produced by the deceleration of charged particles through matter. Usually associated with energetic beta emitters, e.g., ^{32}P.

Calibration
Determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary.
correction factors. The check or correction of the accuracy of a measuring instrument to assure proper operational characteristics.

Cation

A positively charged ion.

Charged Particle
An ion. An elementary particle carrying a positive or negative electric charge.

Chronic Exposure

The absorption of radiation (or intake of radioactive materials over a long period of time), i.e., over a lifetime.

Committed Dose Equivalent
The dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed Effective Dose Equivalent
The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

Contamination, Radioactive
Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm caused may be a source of excessive exposure to personnel or the validity of an experiment or a procedure.

Controlled Area
An area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason.

Cosmic Radiation
Penetrating ionizing radiation, both particulate and electromagnetic, originating in space. Secondary cosmic rays, formed by interactions in the earth's atmosphere, account for about 45 to 50 millirem annually.

Coulomb
The meter-kilogram-second unit of electric charge, equal to the quantity of charge transferred in one second by a constant current of one ampere.

Count
The external indication of a device designed to enumerate ionizing events. It may refer to a single detected.
event or to the total registered in a given period of time. The term is often erroneously used to designate a
disintegration, ionizing event, or voltage pulse.

Critical Organ
The organ or tissue, the irradiation of which will result in the greatest hazard to the health of the individual or his descendants.

Curie
The quantity of any radioactive material in which the number of disintegrations is 3.7×10^{10} per second. Abbreviated Ci.

Daughter Products

Isotopes that are formed by the radioactive decay of some other isotope. In the case of ^{226}Ra for example, there are ten successive daughter products, ending in the stable isotope ^{206}Pb.

Decay, Radioactive
Disintegration of the nucleus of an unstable nuclide by the spontaneous emission of charged particles and/or photons.

Declared Pregnant Worker
A woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Delayed Health Effects
Radiation health effects which are manifested long after the relevant exposure. The vast majority are stochastic, that is, the severity is independent of dose and the probability is assumed to be proportional to the dose, without threshold.

Decontamination
The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination, (2) letting the material stand so that the radioactivity is decreased as a result of natural decay, and (3) covering the contamination to shield or attenuate the radiation emitted.

Deep Dose Equivalent
Applies to external whole-body exposure and is the dose equivalent at a tissue depth of one centimeter (1000 mg/cm^2).

Department of Transportation (DOT)
A governmental agency responsible for promoting the safe transportation of hazardous materials by all modes (land, air, water).

Depleted Uranium
Uranium having a percentage of ^{235}U smaller than the 0.7% found in natural uranium. It is obtained from spent (used) fuel elements or as byproduct tails, or residues, from uranium isotope separation.

Derived Air Concentration (DAC)
The concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI.

Disintegration
See decay, radioactive.

Dose or Radiation Dose
A generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section.

Dose Equivalent (H_T)
The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and the Sievert (Sv). The ICRP defines this as the equivalent dose, which is sometimes used in other countries.

Dose Rate

The radiation dose delivered per unit of time. Measured, for example, in rem per hour.

Dosimeter

A portable instrument for measuring and registering the total accumulated exposure to ionizing radiation. (see dosimetry.)

Dosimetry

The theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made (see film badge; thermoluminescent dosimeter; Geiger-Mueller counter).

Effective Dose Equivalent

The sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to
each of the body organs or tissues that are irradiated.

Efficiency (radiation detection instrument)

A measure of the probability that a count will be recorded when radiation is incident on a detector. Usage varies considerably so be aware of which factors (window, transmission, sensitive volume, energy dependence, etc.) are included in a given case. At Wayne State University, we are referring to the percent of total activity present for a given nuclide detected by the radiation detection instrument being used.

Electromagnetic Radiation

A traveling wave motion resulting from changing electric or magnetic fields. Familiar electromagnetic radiations range from x-rays (and gamma rays) of short wavelength, through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wavelength. All electromagnetic radiations travel in a vacuum with the velocity of light (see photon).

Electron

Negatively charged elementary particle which is a constituent of every neutral atom. Its unit of negative electricity equals 4.8×10^{-19} coulombs. Its mass is 0.000549 atomic mass units.

Electron Capture

A mode of radioactive decay involving the capture of an orbital electron by its nucleus. Capture from the particular electron shell is designated as "K-electron capture," "L-electron capture," etc. X-rays are produced.

Electron Volt

A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of 1 volt. Abbreviated eV. Radioisotopic energy is typically measured in MeV. (million electron volts).

Erg

The unit of energy or work in the centimeter-gram-second system; the work performed by a force acting over a distance of one centimeter so as to result in a one gram mass being accelerated at a rate of one centimeter per second each second.

Exposure

(1) Being exposed to ionizing radiation or radioactive material. (2) a measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of air in the volume element. The special unit of exposure is the Roentgen

External Dose
That portion of the dose equivalent received from radiation sources outside the body.

Extremity
Hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Eye Dose Equivalent
Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm^2).

Film Badge
A packet of photographic film used for the approximate measurement of radiation exposure for personnel monitoring purposes. The badge may contain two or more films of differing sensitivity, and it may contain filters which shield parts of the film from certain types of radiation.

Fission
The splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

Gamma Ray
Very penetrating electromagnetic radiation of nuclear origin. Except for origin, identical to x-ray.

Geiger-Mueller (G-M) Counter
A radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation.

Gray
The international (SI) unit of absorbed dose in which the energy deposited is equal to one Joule per kilogram (1 J/kg).

Half-Life, Biological
Time required for the body to eliminate 50 percent of a dose of any substance by the regular processes of elimination. This time is approximately the same for both stable isotopes and radionuclides of a particular element.

Half-Life, Effective
Time required for a radioactive nuclide in a system to be diminished by 50 percent as a result of the combined action of radioactive decay and biological elimination.

Effective half-life = Biological half-life x Radioactive half-life
Biological half-life + Radioactive half-life

Half-Life, Radioactive

Time required for a radioactive substance to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

Half Value Layer
The thickness of any specified material necessary to reduce the intensity of an x-ray or gamma ray beam to one-half its original value.

Health Physics
A term in common use for that branch of radiological science dealing with the protection of personnel from harmful effects of ionizing radiation. The science concerned with the recognition, evaluation and control of health hazards from ionizing and non ionizing radiation.

High Radiation Area
An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in one hour at thirty centimeters from the radiation source or from
any surface that the radiation penetrates.

Hot Spot
The region in a radiation/contamination area in which the level of radiation/contamination is noticeably greater than in neighboring regions in the area.

Individual Monitoring Devices
Devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters (TLDs), pocket ionization chambers, and personal air sampling devices.

Intake
Quantity of material introduced into the body by inhalation, ingestion or through the skin (absorption, puncture, etc.)

Inverse Square Law
The intensity of radiation at any distance from a point source varies inversely as the square of that distance.
For example: if the radiation exposure is 100 R/hr at 1 inch from a source, the exposure will be 0.01 R/hr at
100 inches.

Ion
An atom that has too many or too few electrons, causing it to be chemically active; such as an electron that is not associated (in orbit) with a nucleus. Ions may be positively or negatively charged, and vary in size.

Ionization
The process by which a neutral atom or molecule acquires either a positive or a negative charge.

Ionizing Radiation
Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Examples,
alpha, beta, gamma, x-rays, neutrons and ultraviolet light. High doses of ionizing radiation may produce severe skin or tissue damage.

Ionization Chamber

An instrument designed to measure the quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

Ionizing Radiation
Alpha particles, beta particles, gamma rays, x-rays, neutrons, high speed electrons, high speed protons, and
other particles or electromagnetic radiation capable of producing ions.

Isotopes
Nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but
differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties
exist between isotopes of a particular element.

Kinetic Energy
The energy that a body possesses by virtue of its mass and velocity, the energy of motion.

Joule
The meter-kilogram-second unit of work or energy, equal to the work done by a force of one Newton when its point of application moves through a distance of one meter in the direction of the force.

Labeled Compound
A compound consisting, in part, of labeled molecules. By observations of radioactivity or isotopic composition this compound or its fragments may be followed through physical, chemical or biological processes.

LD $_{50/60}$
The dose of radiation expected to cause death within 60 days to 50 percent of those exposed.

Licensed Material
Source material, special nuclear material, or byproduct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Nuclear Regulatory Commission.

Licensee
The holder of the license.

Limits
The permissible upper bounds of radiation exposures, contamination or releases.

Member of the Public
An individual in a controlled or unrestricted area (who is not a radiation worker). However, an individual is not a member of the public during any period in which the individual receives an occupational dose.

Microcurie (uCi)
One-millionth of a curie. (1/1,000,000), (0.000001 Ci) (See Curie.)

Millicurie (mCi)
One-thousandth of a curie. (1/1000th), (0.001 Ci) (See Curie.)

MilliRoentgen (mR)
A sub-multiple of the Roentgen equal to one-thousandth (1/1000th) of a Roentgen. (see Roentgen.)

Minor
An individual less than 18 years of age, as pertains to radiation exposure limits, works with radioactive materials (not a member of the general public).

Molecule
A group of atoms held together by chemical forces. A molecule is the smallest unit of a compound that can
exist by itself and retain all its chemical properties.

Monitoring
The measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive
material and the use of the results of these measurements to evaluate potential exposures and doses.

Natural Radiation
Ionizing radiation, not from manmade sources, arising from radioactive material other than the one directly
under consideration. Natural radiation due to cosmic rays, soil, natural radiation in the human body and other sources of natural radioactivity are always present. The levels of the natural radiation vary with location, weather patterns and time to some degree.

Neutron
Elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral. It has a half-life in minutes and decays in a free state into a proton and an electron.

Non-Removable Contamination
Contamination adhering to the surface of structures, areas, objects or personnel and will not readily be picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts.

NARM
Any naturally occurring or accelerator produced radioactive materials. It does not include byproduct, source, or special nuclear material.

Neutron
An uncharged elementary particle with a mass slightly greater than that of the proton, and found in the nucleus of every atom heavier than hydrogen.

NORM

Naturally occurring radioactive materials.

Nuclear Regulatory Commission (NRC)
An independent federal regulatory agency responsible for licensing and inspecting nuclear power plants, universities and other facilities using radioactive materials.

Nucleus
The small, central, positively charged region of an atom that carries essentially all the mass. Except for the nucleus of ordinary (light) hydrogen, which has a single proton, all atomic nuclei contain both protons and neutrons. The number of protons determines the total positive charge, or atomic number; this is the same for all the atomic nuclei of a given chemical element. The total number of neutrons and protons is called the mass number.

Nuclide
A species of atom characterized by its mass number, atomic number, and energy state of its nucleus, provided that the atom is capable of existing for a measurable time.

Occupational Dose
The dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation and to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical
research programs, or as a member of the general public.

Particle Accelerator
Any machine capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually in excess of 1 MeV. The National Superconducting Cyclotron Laboratory at Michigan State University is a particle accelerator.

Photon
A quantum (or packet) of energy emitted in the form of electromagnetic radiation. Gamma rays and x-rays are examples of photons.

Pig
A container (usually lead or plastic) used to ship or store radioactive materials. The thick walls protect the
person handling the container from radiation. Large containers are commonly called casks.

Pocket Dosimeter
A small ionization detection instrument that indicates radiation exposure directly. An auxiliary charging device is usually necessary.

Positron
Particle equal in mass, but opposite in charge, to the electron; a positive charge.

Principal Investigator (P.I.)
A faculty member, assistant professor or higher (no visiting faculty), appointed by the licensee, who has been approved through the Radiation Safety Committee for the purchase and use of radioactive materials.

Protective Barriers
Barriers of radiation absorbing material, such as lead, concrete, plaster and plastic, that are used to reduce radiation exposure.

Proton
An elementary nuclear particle with a positive electric charge located in the nucleus of an atom.

Public Dose
The dose received by a member of the public from exposure to radiation and to radioactive material released by a licensee, or to another source of radiation. It does not include occupational dose or doses received from background radiation, as a patient from medical practices, or from voluntary participation in medical research programs.

Quality Factor (Q)
A modifying factor that is used to derive dose equivalent from absorbed dose. It corrects for varying risk potential due to the type of radiation.

Rad
The special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 62.4 X 10^6 MeV per gram.

Radiation Area
An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in one hour at thirty centimeters from the radiation source or
from any surface that the radiation penetrates.

Radiation Worker
An individual who uses radioactive materials under the licensees control. Individuals must be trained and have passed a radiation safety examination prior to beginning work with radioactive materials.

Radiography
The making of shadow images on photographic film by the action of ionizing radiation.

Radioisotope
A nuclide with an unstable ratio of neutrons to protons placing the nucleus in a state of stress. In an attempt
to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.

Radiology
That branch of medicine dealing with the diagnostic and therapeutic applications of radiant energy, including x-rays and radioisotopes.

Radionuclide
A radioactive isotope of an element.

Radiosensitivity
The relative susceptibility of cells, tissues, organs, organisms, or other substances to the injurious action of
radiation.

Radiotoxicity
Term referring to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioactive material introduced into the body.

Reference Man
A hypothetical aggregation of human physical and physiological characteristics arrived at by international
consensus. These characteristics may be used by researchers and public health workers to standardize results of experiments and to relate biological insult to a common base.

Relative Biological Effectiveness

For a particular living organism or part of an organism, the ratio of the absorbed dose of a reference radiation that produces a specified biological effect to the absorbed dose of the radiation of interest that produces the same biological effect.

REM
The English unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, distribution factor, and any other necessary modifying factors.

Removable Contamination
Contamination deposited on the surface of structures, areas, objects or personnel that can readily be picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts.

Restricted Area
An area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

Roentgen (R)
The quantity of x or gamma radiation such that the associated corpuscular emission per 0.001293 gram of dry air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign. Amount of energy is equal to 2.58×10^{-4} coulombs/kg air. The Roentgen is a measure of exposure.

Scintillation Counter
An instrument in which light flashes produced in a scintillator by ionizing radiation are converted into electrical pulses by a photomultiplier tube.

Sealed Source
Radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions which are likely to be encountered in normal use and handling.

Shallow Dose Equivalent
Applies to the external exposure of the skin or an extremity and is taken as the dose equivalent at a tissue
depth of 0.007 centimeter (7 mg/cm^2) averaged over an area of one square centimeter.

Shielding Material
Any material which is used to absorb radiation and thus effectively reduce the intensity of radiation, and in
some cases eliminate it. Lead, concrete, aluminum, water and plastic are examples of commonly used shielding material.

Sievert
The international unit (SI) of dose equivalent (DE, human exposure unit), which is equal to 100 rem. It is obtained by multiplying the number of grays by the quality factor, distribution factor, and any other necessary modifying factors.

Site Boundary
The line beyond which the land or property is not owned, leased, or otherwise controlled by the licensee.

Somatic Effects of Radiation
Effects of radiation limited to the exposed individual, as distinguished from genetic effects, which may also
affect subsequent unexposed generations.

Source Material
1. Uranium or thorium in any combination of uranium and thorium in any physical or chemical form; or
2. Ores that contain, by weight, one-twentieth of 1 percent (0.05%), or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.

Special Nuclear Material
1. Plutonium, ^{233}U, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the Nuclear Regulatory Commission determines to be special nuclear material, but does not include source material; or
2. Any material artificially enriched by any of the foregoing but does not include source material.

Specific Activity
Total radioactivity of a given nuclide per gram of a compound, element or radioactive nuclide.

Stable Isotope
An isotope that does not undergo radioactive decay.

Stochastic Effects
Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Survey
An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer,
release, disposal or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Terrestrial Radiation
The portion of the natural radiation (background) that is emitted by naturally occurring radioactive materials in the earth.

Thermoluminescent Dosimeter (TLD)
Crystalline materials that emit light if they are heated after being they have been exposed to radiation.

Total Effective Dose Equivalent (TEDE)
The sum of the deep dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Tracer, Isotopic
The isotope or non natural mixture of isotopes of an element which may be incorporated into a sample to
make possible observation of the course of that element, alone or in combination, through a chemical, biological, or physical process. The observations may be made by measurement of radioactivity or of isotopic abundance.

Tritium
A radioactive isotope of hydrogen (one proton, two neutron). Because it is chemically identical to natural hydrogen, tritium can easily be taken into the body by any ingestion or inhalation path. Decays by beta emission. Its radioactive half-life is about 12.5 years.

Unrestricted Area
An area, access to which is neither limited nor controlled by the licensee.

Unstable Isotope
A radioisotope.

Uptake
Quantity of material taken up into the extracellular fluids. It is usually expressed as a fraction of the deposition in the organ from which uptake occurs.

Very High Radiation Area
An area accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at one meter from a radiation source or from any surface that the radiation penetrates.

Weighting Factor (W_T)
For an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that
organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. Presently,
the organ dose weighting defined by the NRC and the ICRP differ.

Whole Body
For purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

Wipe (smear or wipe test)
A procedure in which a swab, e.g., filter paper or cotton tipped applicator, is rubbed on a surface and its radioactivity measured to determine if the surface is contaminated with loose (removable) radioactive material.

X-rays
Penetrating electromagnetic radiations having wave lengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the
extranuclear part of the atom as x-rays. These rays are sometimes called Roentgen rays after their discoverer, W.C. Roentgen.